

THESIS ON POWER ENGINEERING,
ELECTRICAL ENGINEERING, MINING ENGINEERING D52

**Research and development of an
Active Learning Technology for
University-Level Education in the Field of
Electronics and Power Electronics**

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TUT
PRESS

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been submitted for any academic degree.

Zoja Raud.....

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ENERGEETIKA. ELEKTROTEHNIKA. MÄENDUS D52

**Aktiivõppetehnoloogia uurimine ja
väljatöötamine kõrghariduse
õppekavale elektroonika ja
jõuelektroonika valdkonnas**

ZOJA RAUD

Contents

Acknowledgements	8
Abbreviations	9
Symbols	9
Introduction	10
I.1. Motivation and Background	10
I.2. Objectives and Tasks	12
I.3. Major Results	12
I.4. Thesis Outline	14
Chapter 1. State of the Art of Educational Technologies in Engineering	16
1.1 Problems and Tendencies of Engineering Education.....	16
1.1.1 Actual problems of engineering education	16
1.1.2 Major tendencies in engineering education.....	17
1.1.3 Active learning technology	19
1.1.4 Resume	20
1.2 Challenges and Enhancements in Engineering Education.....	21
1.2.1 E-learning techniques: e-labs and remote labs.....	21
1.2.2 Challenges in assessment procedures.....	23
1.2.3 Enhancement of learning management	27
1.2.4 Resume	28
1.3 Management of Learning Electronics and Power Electronics	29
1.3.1 Procedural model of an educational system.....	29
1.3.2 Object model of an educational system	30
1.3.3 Flowchart of TUT curricula in Electronics and Power Electronics	32
1.3.4 Drawbacks of the traditional approaches	34
1.3.5 Resume	36
1.4 Research of Students' Expectations and Opinions.....	36
1.4.1 Survey organisation.....	36
1.4.2 Students' expectations, requirements, and possibilities.....	37
1.4.3 Analysis of the survey	39
1.4.4 Resume	40
1.5 Summary of Chapter 1	40
Chapter 2. Development of Knowledge Models on the Base of Educational Thesauri	41
2.1 Analysis of the Traditional Thesauri.....	41
2.1.1 Concepts and thesauri	41
2.1.2 Case study in Electronics	44
2.1.3 Principles of arrangement of educational thesauri	45

2.1.4 Resume	47
2.2 Algorithmization of Thesaurus Assembling	47
2.2.1 Class-built model of an educational thesaurus.....	47
2.2.2 The problem of assembling a thesaurus	49
2.2.3 Ranking algorithm.....	50
2.2.4 Resume	52
2.3 Concept Tree and User Interface of the Educational Thesaurus.....	53
2.3.1 Application example from Electronics.....	53
2.3.2 Application example from Power Electronics	56
2.3.3 Thesaurus as a tool for teaching and learning.....	58
2.3.4 Resume	62
2.4 Summary of Chapter 2	62
Chapter 3. Arrangement of Active Learning for Bachelor’s Study of Electronics and Power Electronics	63
3.1 Development of Active Learning Technology.....	63
3.1.1 Academic performance in the scope of active learning	63
3.1.2 Enhanced methodology of theoretical training	66
3.1.3 Resources of active learning	67
3.1.4 Resume	68
3.2 Arrangement of Exercises in Electronics and Power Electronics.....	69
3.2.1 Modelling and simulation throughout active learning	69
3.2.2 Exercise lessons organisation.....	70
3.2.2 Exercise implementation	73
3.2.4 Contents of exercises in Electronics	75
3.2.5 Contents of exercises in Power Electronics	77
3.2.6 Resume	80
3.3 Arrangement of Labs in Electronics and Power Electronics	80
3.3.1 Review of traditional laboratory practices	80
3.3.2 Organisation of active laboratory learning.....	81
3.3.3 Implementation of laboratory practice	84
3.3.4 Resume	85
3.4 Development of the Self-Assessment System.....	86
3.4.1 Assessment in an active learning context.....	86
3.4.2 Assessment throughout lectures.....	87
3.4.3 Assessment throughout exercises and labs	91
3.4.4 Resume	94
3.5 Summary of Chapter 3	94
Chapter 4. Arrangement of Active Learning for the Master’s Study of the Advanced Course of Power Electronics	96
4.1 Remote Laboratory for Active Learning on the Master’s Level.....	96
4.1.2 Proposed architecture of the remote laboratory	96

4.1.3 Benefits and drawbacks of the remote laboratory.....	99
4.1.4 Resume	102
4.2 Problem-Based and Project-Based Learning	103
4.2.1 Problem-based approach	103
4.2.2 Project-based learning	105
4.2.3 Composite project in the Advanced Course of Power Electronics	106
4.2.4 Resume	110
4.3 Collaborative Learning.....	111
4.3.1 Benefits of collaborative learning	111
4.3.2 Implementation of collaborative learning	111
4.3.3 Resume	114
4.4 Summary of Chapter 4	115
Chapter 5. Development of LCMS and Prospects of the Future Research	116
5.1 Web-Based LCMS to Study Electronics and Power Electronics.....	116
5.1.1 Introduction to LCMS	116
5.1.2 Management of learning objects	118
5.1.3 Development of a LCMS	120
5.1.4 Resume	123
5.2 Management of Learning Content through Social Networking.....	123
5.2.1 Requirements for social networking	123
5.2.2 Development of social networking	124
5.2.3 Analysis of social networking	126
5.2.4 Resume	128
5.3 Prospects of Learning Management Based on Flexible Curricula...	130
5.3.1 Innovative training set-ups and practices in industrial companies	130
5.3.2 Flexible curriculum	131
5.3.3 Defining of the optimal educational trajectories	134
5.3.4 Resume	137
5.4 Summary of Chapter 5	137
Conclusions	139
References	142
Web Links	154
Publications of the Author	156
Abstract	160
Kokkuvõte.....	161
Annex	162
Curriculum Vitae.....	162
Lisa	164
Elulookirjeldus	164

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ABBREVIATIONS

ac – alternating current
BOAL – Budapest Open Access Initiative
dc – direct current
ECP – European Credit Point
ECTS – European Credit Transfer and Accounting System
EHEA – European Higher Education Area
EQF European Qualification Framework
ET – Educational Thesaurus
EU – European Union
HTML – HyperText Markup Language
IASTED – International Association of Science and Technology for Development
IEC – The International Electrotechnical Commission
IEEE – The Institute of Electrical and Electronics Engineers
IIS – The International Institute of Informatics and Systemics
LCMS – Learning Content Management System
LMS – Learning Management System
OER – Open Educational Resources
OIS – Õppeinfosüsteem
SME – Small and Medium Enterprises
TUT – Tallinn University of Technology
WSEAS – The World Scientific and Engineering Academy and Society

SYMBOLS

A – number of assessments
 CON – defined concept
 ECP – number of credit points
 D – concept definition function
 DIS – discipline
 H – number of hours
 i – index of a concept
 j – index of a parent
 k – index of a discipline
 K – number of disciplines
 m – number of concepts in the discipline thesaurus
 M – number of concepts in the speciality thesaurus
 p – number of parents in the concept definition function
 S – number of semesters
 T – term of the parent concept
 $Term$ – concept term
 w – binary connection weight

INTRODUCTION

I.1. Motivation and Background

Electronic engineering, science, and technology are penetrating to all possible aspects of human life aiming their improvement. In fact, electronics influences every aspect of global industry and social activity. Electronics has a strong impact on many fields, ranging from telecommunications and information processing to machine tool, robotics, medicine, and transportation. Its key applications include residential and commercial appliances, power supplies, motor control, automotive systems, and electric power conditioning and distribution.

The demands of the economy in the 21st century and the effects of globalisation need that the contemporary graduates acquire abilities in mastering their professions along with leadership and information management, autonomous and collaborative skills, broad cultural backgrounds, concept synthesis, and decision-making activities. In view of the deep world transformation, engineering companies expect an aptitude of education to accomplish its noble mission of training the future generations of people. Formation of a new kind of a specialist is the priority to face the novel world environment the aspects of which are not always positive.

Today, many institutions seek better ways to enhance their educational technologies which, according to the UNESCO documents, should provide novel organisational arrangements for creation, application, and defining teaching and learning processes and resources with their interaction. The main objectives are to arrange high-quality education that motivates students to learn not only the skills directly related to their speciality, but also the additional knowledge domains valuable in the professional working environment.

This thesis presents the results of the research conducted at the Department of Electrical Drives and Power Electronics of Tallinn University of Technology (TUT) along with the activities of the most reputable world's professional associations related to electronic engineering education. First, being an IEEE member [WL23], the author supported the guidelines of the IEEE Educational Society. Second, through the IIS membership [WL25] the author followed the major educational directions mapped by this institution. Next, the recommendations of the Educational Board of the World Scientific and Engineering Academy and Society WSEAS [WL26] were involved in the scope of the thesis problems. As well, this research followed the activities of the Committee for Advanced Technology in Education of The International Association of Science and Technology for Development (IASTED) [WL24]. Finally, the author has benefited considerably from the participation in such famous international community as Educational Department of EUROSIS [WL22]. An integrated topological scheme of the developed technology is presented in Figure I1. It involves the methodical, algorithmic, software, documental, and engineering tools intended for learners, educators, and administrative staff.

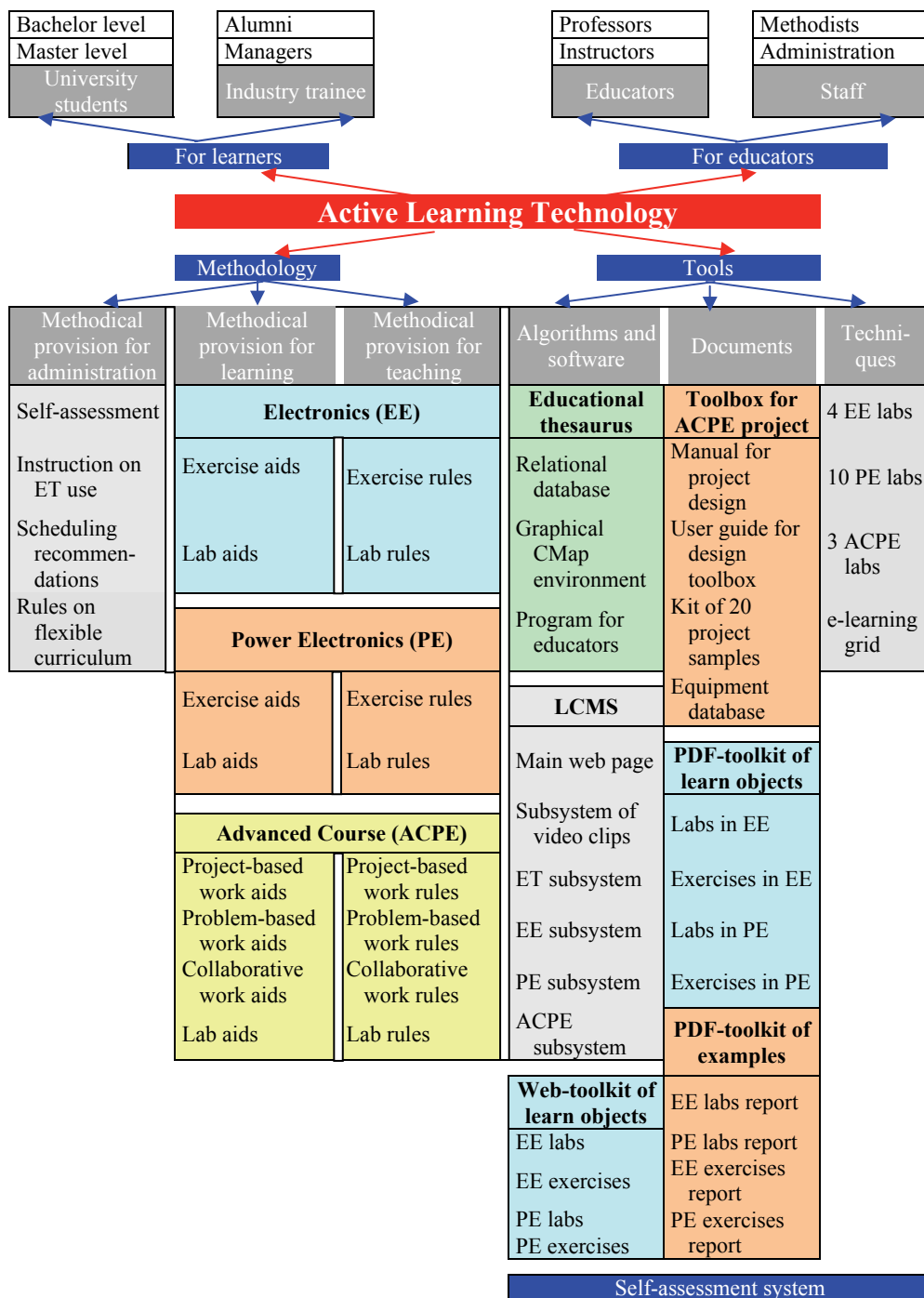


Figure I.1. Integrated topological scheme of the developed technology

Major results of the thesis contribute to both the international and Estonian education and economy. The most significant part of the thesis is available through Estonian National e-Learning Portal [WL06]. The learning, teaching, and administrative resources developed in the scope of the current research became the part of the National Educational Repository [WL06] and were awarded by the Letter of Recommendation from the Estonian Ministry of Education and Research [WL05].

Besides TUT, this research was supported by European Social Fund for Doctoral Studies and International Programme DoRa, Estonian Kristjan Jaak Scholarships, Estonian Archimedes Foundation Project DAR 8130 “Doctoral School of Energy and Geotechnology II”, and Estonian Science Foundation Grants ETF 8020 and ETF 7572.

I.2. Objectives and Tasks

The first objective of this study is to research and develop the methods and tools that attract learners and educators in making the educational process in the field of Electronics and Power Electronics maximally effective and successful. Another objective of the thesis is to enlarge the students’ and teachers’ opportunities of knowledge acquisition and appreciation. The third important objective of the presented work is to develop a suitable informational environment to provide the participants of the educational process with the new active learning tools.

The main research tasks of the thesis were as follows:

- to develop the theoretical, methodical, and algorithmic provision for the thesauri-based curricula-supporting system
- to design the new Web-accessible objects and Internet services for implementation of an active learning technology in the field of Electronics and Power Electronics
- to create an effective learning content management system supporting the learners in sharing information, peer-to-peer collaboration, uploading and exchanging the content they have created, based on common interests or pursuits

I.3. Major Results

The **scientific contributions** of the thesis, which are considered as new, can be summarised as follows:

- a learning/teaching technology built on a novel conception of educational thesaurus, including its mathematical base, simulation methods, and applications

- new tools for the bachelor and master study that extend the sphere of the active learning technology across the field of electronics and power electronics
- a learning content management system covering the field of electronics and power electronics, including the Web organisation and the social networking environment

The **practical value** of the thesis is as follows:

- an increased skill area of the graduate students and the graduates
- enlarged possibilities for students to acquire and share knowledge and skills
- enhanced descriptiveness and attractiveness of learning
- effective instruments for information search, comparison and evaluation
- suitable tools for onsite and off-site education, including staff consulting and peer-to-peer collaboration
- an easy self-assessment environment with fast feedback and learning correction

The **direct practical outcomes** of the thesis are as follows:

- an enhancement of the students' skill in the field confirmed by the professional quizzes and examination grades
- an increased evaluation of the new learning by the students confirmed by official university statistics
- an enlarged learners' favour to the disciplines and to the speciality confirmed by the lesson and exam attendance

Confirmation and dissemination of results are based on both the theoretical and practical investigations. The mathematical apparatus used in the thesis includes the procedural analysis, object-oriented approach, matrix derivation, statistics, theory of syntax, and search methods based on the relational databases and the family trees.

The profitability of the work has been confirmed by analytical exploration and computer simulation along with verification in the real academic processes.

The results of the thesis were disseminated by their presentation at 28 international conferences and citing in 7 Web portals, including the Estonian National e-Learning Portal. The author has published 30 international scientific works directly associated with the thesis. 20 of the author's papers are presented in collections indexed by IEEE Explorer, ISI-Thomson Reuters, and INSPEC. According to Google Scholar Citations, the author's current h-index is 3.

I.4. Thesis Outline

In **Chapter 1**, the state of the art of educational technologies in engineering, particularly in the field of electronics and power electronics, is outlined. Following the study of the actual problems and the major tendencies in engineering education reported in [Z15], the contemporary challenges and improvements, solutions in learning styles, and advanced learning techniques are summarised. An active learning definition and properties are discussed in [Z4] from the viewpoint of academic performance. An enhancement of e-learning and novel challenges in assessment systems were found in [Z5] based on comprehensive literature overviews. To analyse the progressive features of learning management, the basic model of an educational system was designed [Z10]. Following the object decomposition of such systems, TUT curricula in Electronics and Power Electronics were evaluated and the drawbacks of the traditional approaches were found. A specific survey was conducted to study the students' expectations and opinions [Z12]. The students' needs in the selected speciality, their requirements to the knowledge and skill levels, and study possibilities were explored carefully.

Chapter 2 is devoted to the development and application of the new learning/teaching tool called an educational thesaurus. The research was initiated by the analyses of the traditional thesauri shortcomings from an educational viewpoint presented in [Z28], [Z30]. Then, the concepts were introduced as the core components of the thesaurus model. The object-oriented, matrix, and treelike mathematical models are discussed and compared based on several application examples. On the next step, the basic principles of the educational thesaurus arrangement were drafted. Using an object-oriented approach, the set of model classes, their components and procedures were suggested and published in [Z03], [Z10]. To derive the problem of the thesaurus ranking, the matrix model was arranged and an effective ranking algorithm described in [Z09] was developed. An application example presented in [Z23] concerns the concept tree model of the educational thesaurus and its practical implementation.

Chapter 3 describes an active learning methodology around the field of the bachelor's study programme for Electronics and Power Electronics. New methods of theory delivery and assessment, an enhanced methodology of theoretical training, and resources of active learning are proposed. An effective arrangement of exercises in Electronics and Power Electronics, including their contents and implementation mechanisms discussed first in [Z09], [Z11], [Z17] are described and evaluated. The model-based learning methods developed in [Z02], [Z06], [Z07], [Z16] relate to the modelling and simulation processes on the bachelor's level, including the problems of understanding the circuit throughout simulation and modelling instruments for learning electronic circuits. Also, organisation of labs in Electronics and Power Electronics, including a review of traditional approaches, the new organisational principles, and implementation peculiarities are given in conjunction with the research [Z12]. Finally, the original self-assessment system is described. Following

the preliminary remarks about knowledge and skill measurements, an assessment in an active learning context is discussed. An effective methodology of assessment throughout lectures, exercises, and laboratory practice developed in [Z20] is presented.

In **Chapter 4**, an active learning technology focused on the master's study in the Advanced Course of Power Electronics is designed and explored. The problems under the question involve organisation of the remote laboratory for active learning on the master's level, including its aim and scope, architecture and an association with traditional learning techniques. The sample description of the e-laboratory performance, its benefits and drawbacks are presented following the study in [Z01], [Z08]. The project-based and problem-based learning approaches to study Electronics developed in [Z13], [Z19], [Z26] are discussed from the position of their targets and definitions, design objectives and implementation. The new solutions found in [Z14] in the field of the collaborative learning are also given in this chapter. They concern the problems of communication skills for master's students and implementation of the team-based training.

Chapter 5 is directed to the development of an effective learning content management system covering the field of Electronics and Power Electronics. This part of the thesis provides the global prospective of the future research. First, the Web-based educational systems are discussed. Numerous possibilities for management of learning objects are described in [Z21], [Z24] and presented here. The novel approach in the field relates to the social networking in the management of learning [Z27], [Z29]. Following an insight into the social networking problems, the chapter opens a direction of the future development of education on the basis of flexible curricula. Here, the concept of the flexible curriculum introduced in [Z18], [Z22], [Z25] and the solution of the problem of how to define the optimal educational trajectories are offered.

Then, the thesis **Conclusions** are presented.

The **lists** of 142 references sorted by years, [YYxx]; 30 Web links, [WLxx]; 30 author's works, [Zxx]; and 7 author's Web links, [ZLxx] consummate the thesis.

CHAPTER 1. STATE OF THE ART OF EDUCATIONAL TECHNOLOGIES IN ENGINEERING

1.1 Problems and Tendencies of Engineering Education

1.1.1 Actual problems of engineering education

Considering the breadth of the background required to participate in the professional field, education must respond to the technological advances and make appropriate changes in the teaching mission. This section aims to demonstrate the problems and tendencies that have appeared due to imbalance between engineering education in relation to demands in the industry and points out the importance of attracting students to engineering and retaining them in this field. The current state of engineering education is overviewed based on the materials of the 2009–2012 international conferences and special sessions on engineering education in which the author participated with papers. The event list includes IMETI [0901] and EISTA [0902], EUROMEDIA [0904], [1103], EUROCON [0905], [1105], EPE [0903] and EPE-PEMC [1003], EDUCON [1001], [1201], IASTED [1004], [1203], ICIS [1002], INDIN [1102], CPE [1101], SPEEDAM [1104], and WORLD-EDU [1202]. The most important solutions found in this review are used to bring alternatives to the dangerous issues and prevent their negative impacts. Primarily, it concerns the novel active learning technology, advanced learning techniques, and progressive learning management approaches.

The analysis supports many of the tendencies represented by the official European statistics [WL07]. The conference proceedings and discussions indicate that the number of students accessible to higher education is increasing in a sustainable way. Unfortunately, the growth in tertiary studies is not reflected in all educational domains. While the university enrolment is rising, the fields of engineering, mathematics, and natural sciences represent less than 5 % and drop permanently. At the same time, significant overall dropouts occur among engineering students, often above 20 %. The number of graduates in these areas is falling each year, reflecting lack of motivation to follow engineering and scientific careers.

Several studies agree that the reason why a student does not pick engineering or does not feel attracted by technology as a domain of study is related to the image that these careers reflect or to the degree of difficulty that these domains seem to represent. Particularly, one of the main deficiencies in academic education in Europe is the low enrolment to large universities. A negative image of technological studies has been identified as the major reason behind this trend. Researchers point to the lack of knowledge of the engineering. The European orientation research suggested that both the teenagers and undergraduates have unclear understanding of an engineer's activity. Consequently, they do not know the kind of job a professional performs and do not pursue the corresponding degrees as an option relevant to their future career.

Teaching and learning engineering has changed seriously because the contemporary technological solutions, including many interrelated concepts, tend to become very complex. The traditional boundaries of classical engineering disciplines have become indistinct following the advent of information technology and computer science. It is especially evident in mechanics and electronics, where today's appliances and devices consist of an assembly of integrated electrical and mechanical components [0505].

Due to the lack of interest, many participatory methodologies are difficult to implement. This reality is clearly reflected in some institutions, where noticeable parts of students opt for the traditional methods and reject the educational improvements. Both the students and the professors perceive that the workload is heavier whereas attainment is not always predictable.

A significant part of the teaching staff is reluctant in introducing new methods, partly for obvious reasons, such as the increased workload, and partly due to under-motivation in achieving definite educational improvements. On the other hand, students often tend to simplify their study approaches to minimize the time they spend on courses.

The declining interest in engineering education surprises the more when it comes from the developed countries those industries depend on the technology and constitute a significant change affecting the labour demands. Unresolved, this situation will have a strong negative impact on the future development of society.

1.1.2 Major tendencies in engineering education

An overview of the main problems affecting society means that the involvement of students has to go beyond the scope of teaching exclusively related to their narrow speciality. Since there must be motivation of students who are interested in using tools and devices built for intellectual growth, it is time now to discard traditional pedagogy that leaves very little scope to the student and, instead, to propose a constructivist pedagogy which guides a student to identify and define the problems, find procedures, gather and interpret results, and make decisions.

Contemporary pedagogy has proposed several learning approaches and a close relationship between these attitudes towards learning, including motivation to learn, involvement in learning activities, calls to teachers and self-efficacy. Obviously, students learn better if contents are presented to them through a medium that matches their preferred goals and expectations. Consequently, the engineering community has expressed the necessity to develop new education methods to combine theoretical and practical activities based on the actual products as working examples. There is also a general agreement about the needs of new teaching and assessment strategies to enhance competence-based learning. The whole system matches the constructivist theory and constitutes an interactive computer-based environment.

In June 1999, the education ministers from 29 European countries met in Bologna, Italy, to approve the Declaration for the convergence process towards the European Higher Education Area (EHEA) [WL10]. Global directions of education organisation were outlined in [WL08]. Changes in the global society have motivated the promotion of profound changes in education through EHEA. Year 2010 was set as a deadline to finalise this process which would allow unification of the fundamental questions related to higher education studies in the EU. The basic aims set by EHEA are as follows:

- design a new teaching model focused on the students who become the protagonist of their own learning
- establish a high quality evaluation system based on the student's continuous work
- create a system of university qualifications which will be compatible all round the EU
- set the uniform university credit system in all European countries
- promote student's and lecturer's mobility in higher education establishments

The European Parliament and the EU Council defined and set out the key competences, such as communication in the mother tongue and in foreign languages, mathematical and basic competences in science and technology, digital competence, learning to learn, interpersonal, intercultural, social, and civic competences, entrepreneurship, and cultural expression

To achieve these aims and competences, the most significant changes in EHEA concerned the new vision of the concept of learning. In order to accept the challenges, universities were called to reconsider their structural and educational concepts and to reform their curricula. The traditional university system focused on teaching by the lecturer was requested to turn into the system focused on the student's own learning. In other words, students are summoned to build their own knowledge on the basis of their growing experience and know-how. Encouraged were active teaching methodologies, more personalised monitoring of the student's work, and higher involvement and student autonomy in teaching and learning. Accordingly, engineering education should promote the "habits of mind" that include systematic thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations [0405]. Herein, analytical skills, creativity, ingenuity, professionalism, and leadership are involved. Particularly, EHEA invests huge efforts to foster the conversion of former ways of teaching into the modern styles of learning, which are student-focused, holistic and comprehensive, helpful and encouraging. This activity increases the student's motivation and disposition towards the course, thus enhancing the learning outcomes including teamwork, communication skills and critical analysis.

Another point of EHEA relies on the assessment processes because the traditional methods could not evaluate the student's continuous efforts. This means

that the change in the structure of the university degrees was expected in a way that all the undergraduate and master's degrees in Europe obtain the same grades.

Partnerships of the European member states and their higher education institutions channelled through the Bologna process became the important component of internationalisation [WL09]. Cross-curricular competencies and student's motivation have become the central issues in the new scenario adapting educational models and methodologies to achieve these new priorities.

1.1.3 Active learning technology

The existing educational systems in many institutions are far from being abreast of the future industrial challenges in the field [Z04]. Having realised this disparity between industrial requirements and knowledge imparted to the graduates at various levels, some universities ventured to elaborate series of curricula to meet the future need for skilled human workforce in electronics on the one hand, and to contribute to creation of excellent job opportunities in industries on the other [0505].

Most effective learning methods involve direct, purposeful learning experiences [WL01]. Concrete, reflective, experiential and active learning are some terms used now to describe alternative constructivist pedagogical methods that fit the new learning styles. They are even more required in technical studies in which obviously concepts studied in class must be put into practice in different scenarios so that the students fully understand the fundamentals and acquire the necessary competencies to apply them in solving the real-world problems.

Traditional education covers those activities that people can learn from, but it does not generally boost itself the learning experience. Lecturing is a suitable approach from administrative and teaching points of view. However, its impact on student's knowledge, competences acquisition and consolidation is rather limited. As a consequence, a great part of a student's learning activities depends on his/her personal work.

Learning is a cognitive process of gaining knowledge and skills through schooling, study, observation, practice, etc. At learning, knowledge has to be constructed by the learners' efforts and activities. From this viewpoint, active learning seems extremely prospective as it leads to better understanding and, eventually, to a lesser burden. Many studies have investigated the positive outcomes and value from this approach [0912].

An *active learning* educational technology popularised first in [9101] focuses on the students' desire to learn that moves the responsibility of learning on learners by shifting from time-based to achievement-based education. A well-established precept of educational theory is that people are most strongly motivated to learn things they clearly perceive as a need to know. By providing learning through question formulation and finding appropriate resolutions and issues, a student-centred approach is realised where the students take ownership of their learning. For

that, the role of the academicians changes from the “oracle” dispensing knowledge to that of a “facilitator” guiding and supporting the students in their own learning.

The objectives of active learning are to expand significantly the educational opportunities for different groups of students, both the strong and the weak ones. The following aims of active learning were announced:

- students motivation in learning contemporary engineering concepts
- students engaging with materials they study
- development of reasoning skills and understanding of the studied material
- articulating and testing of the ideas through experimentation and discussion

Using this approach the students construct their own knowledge through learning skills, exploration, feedback evaluation, and reflection, based on their own experience [0801]. Educators have always been early adopters to use new technologies within their field. It is argued that an instructor would give guidance and support and thus help learners to become actively involved in the learning process. Hence, intensive and direct teaching of learning strategies, including practice and training in the use of those tools, helps the students to succeed in their learning. Following the context of active learning, practice and exercises become the most important stage of engineering training whereas lecturing moves to the auxiliary role.

Different active learning techniques were implemented to obtain the best results in education [0002]. Some examples of this technology are inquiry learning, case-based teaching, discovery learning, and just-in-time teaching. Many scientists, like [8601], [0005], [0823], support the finding that students who learned how to apply learning strategies have reached higher achievements than those who did not acquire these. Therefore, project-based learning, problem-based learning, collaborative learning, and some similar approaches are the subsets of a larger class of learning techniques broadly known as enquiry-based learning [0002]. These techniques provide learning via formulation questions and finding appropriate resolutions to the questions and issues. They realise a student-centred approach where the students take ownership of their learning and are active participants in the process. They all require the students to develop the research skills and methodologies associated with the particular disciplines.

1.1.4 Resume

1. In this section, an analysis of the promoted innovative setups and practices of educational systems was conducted.

2. An overview of the current state of education shows the declining interest in engineering education expressed in the drop of the university enrolment in engineering, significant overall dropouts, and lack of motivation to follow engineering and scientific careers.

3. According to the analysis, the engineering community suffers the necessity to develop new education technologies that combine theoretical and practical activities based on the constructivist pedagogy which guides a student to identify and define the problems, find procedures, gather and interpret results, and make decisions.

4. Global directions of education organisation outlined in the Bologna Declaration promote an active learning technology that moves the responsibility of learning on learners by shifting from time-based to achievement-based education.

1.2 Challenges and Enhancements in Engineering Education

1.2.1 E-learning techniques: e-labs and remote labs

E-learning, known also as web-based learning and online learning, is a set of applications and processes, such as computer-based learning, computer-managed learning, and virtual learning that enhances the possibility for students to attend lessons in remote locations, at a physical distance, being able to be at any place and to communicate actively by means of computers and networks. In contrast to education delivered solely in the classroom, e-learning provides the separation of the teacher and learner in space and time where administrative processes (registration, control, scheduling, guiding, reporting) are facilitated by information systems. Independently of a technology used, all e-learning scenarios define the similar roles throughout different network topologies linked by the common platform. The paths exist between entities with the potential for content transfer (e.g. content preparation, supervision, evaluation, queries, etc.), educators, and learners. A group of channels determines communication between students and local professors from the host universities and remote instructors from outer organizations and communities. In any case, it is essential for the instructors to supervise topics, methodologies, assessments and content developed by students. Numerous components of learning are arranged now into the digital repositories, like [WL06], targeted to the acquisition of different assets of knowledge, skill, or competence. They have become the contextualised, complete, self-contained components of education and training that include teaching methods and associated contents.

Involvement of science and engineering students in the practical work is a fundamental precondition of appreciation of the professional concepts and processes [Z05]. Any contemporary practical course, especially in undergraduate engineering and science studies, requires large amounts of resources, equipment and work force. Unfortunately, many universities are not able to provide the laboratory capacity for the numerous students due to the high costs involved.

Unlike the conventional laboratory where students are to be physically present in the workplace interacting directly with laboratory equipment and communicating face-to-face with classmates and instructors, an *e-lab*, called also a *virtual laboratory*, is presented by different kinds of simulation environment to perform virtual experiments. The software interface to provide the control of the remote

experiment may be custom-built or designed using commercially available solutions. Students perform virtual experiments by interacting with the software interface and observing the on-screen results.

As usual, such virtual laboratories simulate the physical phenomena of a real setup with the computer software helping to understand the real equipment and processes. Nowadays, there is an increasing popularity in virtual laboratory environment for its prominent advantages of intuition and interactivity between teaching and studying. These instruments accompanied by modern educational theories configure a tool that currently has a very important impact on students of all areas of science and technology and plays an important role in the educational process. Besides, virtual laboratory can also benefit distance education and learning-on-the-job trainee, who maybe asynchronous in time or in space, even more, for the cost and time needed for travelling to a local lab would often prevent them from using such real laboratories. Moreover, the virtual laboratory resources can be shared by many institutions and students worldwide saving much time and money.

The above described simulation tools became popular due to the high cost of the maintenance and purchase of real labs. However, despite the advantages – low cost and relative ease to employ – simulators cannot efficiently replicate noise, frequency responses, digital-to-analogue conversion and other physical phenomena that characterise the real systems. Therefore, real laboratory experiments continue to play an essential role in engineering education. They complement theoretical lectures and illustrate and validate analytical concepts, which introduce students to professional practice, social development and teamwork skills in a technical environment. These reasons explain the student's high expectations for laboratory activities.

Introduction of *distance laboratories*, or *remote labs*, enables remote implementation of experiments from anywhere at any time. Contrary to e-labs, a remote experiment is performed on physical equipment housed in a real laboratory, but is controlled by the student remotely, typically communicating with the laboratory equipment across the Internet. A remote lab is a laboratory, the devices and plants of which are tested, controlled, monitored and programmed through a client program or web browser at a remote computer. Sometimes, virtual laboratories and remote laboratories are combined together.

These new technologies offer the capabilities and flexibilities of the software while keeping important characteristics of physical systems and distance laboratory applications. It is obvious that the remote facilities constitute the most realistic method of performing many experiments in engineering distance education courses.

However, establishing and maintenance of remote laboratories is technically very demanding and costly. Therefore, the practical use of such laboratories in regular education of many learners is still not very common. One of the possibilities to ease the burden of establishing remote laboratories with high number of experiments and courses is to share them among the partners. An example of such

sharing is the laboratory implemented within the Leonardo da Vinci e-learning Distance Interactive Practical Education (EDIPE) project [0701], [WL20] the courses of which are offered by thirteen universities from eleven European countries within the same common functionality. Herein, remote experiments make students reachable in an environment to obtain, retrieve, and facilitate access to synchronous collaboration and production generation. They do not only integrate experiments and laboratories into a universe infrastructure, but also help to build virtual portals to provide experiments including the on-line course systems guiding users through experiments. Such portals give access to an integrated environment, which includes a tutoring system as a collaboration area for students, teachers and researchers, providing an organisational framework for online collaboration. From the technical point of view, they serve as a repository of virtual laboratories and remote experiments on central servers that make it possible to include metadata in labs and experiments, to integrate them in search engines, and to link different technologies.

Starting from the 1990s, a growing scale of researches has appeared that validate both the technological viability of distance laboratories and their effectiveness in delivering a worthwhile laboratory experience. The quality of the architectures and designs has steadily improved [0402]. New approaches to learning have been promoted across the entire education sector as more and more people are educated in institutions and they educate themselves after work or as part of the professional development [0702]. Numerous systems are described, which are particularly suited to “predict and measure” remote experiments in electronics and power electronics focusing on analytical and experimental learning [0404], [0502].

1.2.2 Challenges in assessment procedures

Higher education institutions have not yet adopted common standards for learning outcome definitions and assessment results. Nevertheless, educational organisations are regularly accountable to demonstrate the effectiveness of their curricula and syllabi. Previously, engineering criteria required universities to report numerical summaries that reflected their programs and resources and to focus on “inputs” (e.g., number of credit hours, volumes in the library, faculty with PhDs) rather than “outcomes” (what students know and are able to do). Nowadays, higher education has experienced numerous calls for increased accountability. The modern engineering programs must demonstrate that their graduates have the following abilities:

- to use the techniques, skills, and contemporary tools necessary for engineering practice
- to apply knowledge of fundamental and applied sciences
- to plan and conduct experiments along with data analysis and interpretation
- to design systems, components, and processes that meet desired needs
- to function as a part of multidisciplinary teams
- to identify, formulate, and solve engineering problems

- to feel professional and ethical responsibility
- to communicate effectively
- to understand the impact of engineering solutions in a global and societal context
- to recognise the need for and to engage in lifelong learning
- to have a knowledge of contemporary issues

An engineering education community responded quickly to these requirements. New qualitative criteria increased activity within engineering education to prepare for the new demands, which, in turn, eventually led to the revision of the accreditation process. This resulted in further pressure for institutions to establish and implement effective assessment within their curricula. Assessment moved from an off-topic to the centre of engineering education discussions. With the new criteria, institutions must now demonstrate through assessment and evaluation that they are reaching the desired outcomes. Assessment of student outcomes became a significant part of the institutional accreditation process. All accredited engineering programs are now reviewed using the revised criteria and are required to demonstrate through assessment that their students have achieved the above listed attributes.

Following [0504], the term *assessment* that refers to an act of collecting data or evidence, it can be used to answer classroom, curricular, or research questions. It has a broader sense than measuring individual student's competencies, such as scores on a classroom exam or homework assignments. *Evaluation* refers to the interpretations that are made of the evidence collected about a given problem.

The advancement of engineering training in many ways depends on an assessment system, therefore the high-quality assessments may provide educators with information they can use to move the field forward. In contrast, inadequate or poorly constructed assessments may cause instructors to pursue ineffective paths, resulting in the loss of time, money and energy. The infusion of accepted principles and practices of student assessment has a significant impact on the development of engineering curricula and evaluations in terms of student performance.

Different assessment methodologies support the data collection process. They can be usually divided into two primary types:

- qualitative evaluations that describe the current state of a learner's understanding
- quantitative tools that examine how a student's knowledge changes along with learning

Since a major goal of education is to acquire better material appreciation, learning information is descriptive in nature. Therefore, the qualitative evaluations are often based on various descriptive methods. The main methodologies that have been repeatedly used in descriptive knowledge assessments refer to surveys or abstracts and conversational analysis.

By now, a theoretical foundation for the improvement of traditional assessment has been developed and the new assessment methods have been offered. The range of assessment forms used in higher education has expanded considerably in recent years. New approaches have been designed and implemented in higher education, particularly in electrical engineering instruction [9901]. These forms of assessment have a wide scope, including patchwork text portfolios, quizzes, rubrics, peer and self-assessments, problem-based, and project-based assessments. The notion of the improved assessment is used to denote the assessment types, which differ from the traditional tools, such as testing and essay question examinations. The new assessment favours the integration of evaluation, teaching, and learning; the involvement of learners as the active and informed participants and tasks, which are authentic, meaningful, and engaging. The key features of this assessment provide an active participation of learners in an assessment of their own performance and the development of reflective thinking. Therefore, the evaluation strategy was redefined and reformulated for the goals of active learning to stimulate a learner by an assessment and to receive currently the actual feedback [0821].

The use of *surveys (abstracts)* is a common assessment practice of engineering education. They are typically applied to capture data that generalise the knowledge volume of a student. Surveys can be administered in electronic or paper formats. Since the surveys are the self-report instruments, the quality of the information acquired depends on the extent to which students answer correctly as well as their ability to report accurately. Creating a survey that will elicit valid responses is a difficult and time-consuming procedure. Careful thought must be given to every aspect of the survey development and evaluation, including directions that accompany the survey. Poorly designed surveys can result in data that are difficult or impossible to interpret. The typical drawbacks of the student surveys refer to copying data instead of their generation and generalisation. It seems very difficult for a teacher to distinguish between the student's own and illegal authoring of a survey presented for evaluation. Thus, an additional discussion or testing is required to find the real level of the learner's knowledge.

According to [0003], *conversational analysis* examines how students organise joint action and construct social relations in their activities. It is suitable to use conversational analysis to examine the team interactions in design, laboratory and problem-solving sessions. Using this technique, instructors are able to identify the quality and readiness of a student to team performance.

Quantitative techniques are usually applied as the current assessment procedures. This type of evaluation is appropriate when an intervention such as a new topic has been implemented and there is a desire to compare the effectiveness of the intervention with a previous material. To employ the quantitative techniques, a teacher needs to find the most effective tools by seeking or developing the assessment methods that will draw out the actual information [0401]. Tests and quizzes are the most popular quantitative tools.

It is believed often that creating a *test (quiz)* is simply associated with writing of a list of questions. In reality, the process of test development is much more complex [9603]. Two primary types of questions appear in tests — open-ended and selected-response questions. Open-ended questions require the students to respond using an unstructured, short answer, or essay format. In the selected-response questions, the learners choose their answers from a predetermined list of responses. Open-ended questions are usually analysed by qualitative analysis techniques, whereas the selected-response surveys are normally summarised by quantitative analysis techniques. Both the style of questions and the analysis techniques used for testing depend on the type of information the student obtains. To maximise the data acquired, many instructors design their tests including both open-ended and selected-response approaches. As the purpose of a test is to focus on key components of the learning targets, tests are typically guided using an observational protocol, or a checklist, in which an instructor indicates detailed notes concern a given material [0302].

The evaluation and assessment activities may impact strongly on the overall learning process if they are addressed to give students a mark and ranking, help and motivate them by a quick and continual feedback, drive the syllabus development, and also contribute to the teacher performance analysis. However, most of the traditional methods provide weak feedback with students. In the popular evaluation process whose goal is to qualify or certify the level of the student knowledge at the end of the learning time, mainly “summative” assessment is applied, consisting of a final exam at the end of the teaching semester. This evaluation method has been used extensively because it allows the comparison of the group of students as well as checking their knowledge thresholds. It is cheap in organisational terms, predictable, secure and fair. It is also mandatory by the legal university conditions to determine the students’ final grades indicating their learning level.

Nonetheless, evaluation may be more efficient when it has a narrower focused context of application. *Formative assessment* may be understood as a set of useful tools in order to improve the quality of the teaching-learning process and to adapt the learning objects to the student characteristics and context. It has many advantages over the “summative” assessment as it automates most of the repeatable tasks not depending on the human judgment, such as answering the student questions, storing them, and correcting. There are some successful systems supporting e-assessment based on the forms or questionnaires, such as WebCT.

However, the number of evaluation cycles is limited by the complexity of the assessment process which is composed by many activities and involves professors, students, and university staff. Each step must also be performed with the required security, controlling agents’ communication, detecting forgeries and copies, as well as storing the documental proof of the evaluation. These problems are being solved now by some advanced learning management systems included in the European Qualification Framework (EQF) [WL21] that serves as a translation mechanism across the different national qualifications frameworks in the European countries.

Their implementation helps higher educational institutions and organisations to exchange and compare learning outcomes, link their assessment systems, and improve mobility of learners across European countries.

1.2.3 Enhancement of learning management

Internet is a powerful tool of education. For years, numerous *Learning Management Systems* (LMS) have been used to help students in learning, as well as in increasing their productivity within and outside the classroom. In essence, an LMS is software for planning, delivering, and managing learning events within an organization, including online, virtual classroom, and instructor-led courses. These systems have enabled staff and learners to manage better the learning process and share knowledge. As shown in [1109], practically all the students have succeeded in using the LMS. That result is logical, since the educational process relies on the use of the e-learning system and forces the students to enrol [1010].

An LMS represents a web-based system designed for performing administrative and technical support of the processes associated with education. This ware plays a significant role in the learning environment complying with the following requirements:

- overall management of educational processes, objects, and systems
- compatibility and the ability to work with learning content editors and other LMS
- performance and extendibility of the environment
- multi-language support

In recent years, the university management environment is becoming more and more convenient, effective, and efficient thanks to various projects, such as Student Information System (SIS), LMS-Portal, e-Portfolio, etc. Dependence on the web-based management is increasing in educational and training-delivery institutions. These systems are becoming easily accessible tools for managing courses, learners, grades, and other learning actors.

Web-based social media services, such as wikis, blogs, Facebook, LinkedIn, Last.fm, etc. have recently become known, especially among young people. In such popular social networking sites users can participate intensively in service activities, share contents and opinions, debate and create different kinds of groups for their needs. These media services are also used for educational purposes, for example, as a source of information for students, or as a way of presenting assignments and summaries of the class work. Currently, many advanced LMS include wikis and blogs as the integral subsystems.

Wikis present the on-line editing tools that allow their users to create, comment and navigate collections of documents known as entries. Blogs, also known as weblogs, are the websites containing notes in the inverse chronological order, which are publicly accessible over the Internet offering visitors the possibility of commenting entries. The opportunity for students to build their own learning

networks or communities is also supported by the advanced LMS. People enrolled on the same study programmes or courses use them to meet in social settings, do homework or prepare exams. With such trends, higher engineering institutions obtain a closer look at informal personal and social spaces and practices, which are expanding at a global scale and give students access to potentially valuable resources and experts. In addition, educational scientists consider participation in the learning communities as an integral part of the learning process. Especially, it helps students to develop the high-level skills and competences required by their future employers. Hence, a challenge for academic institutions is to integrate in a proper way the student's practices and environments in the existing institutional systems to take advantage of them. Another challenge is to support the students in their informal communications and in building their learning environments and networks as a next step in increasing digital literacy.

Knowledge data acquisition became an emerging interdisciplinary research area that deals with the development of methods to explore data from the learning context. It concerns the exploring of the unique types of data in educational settings and, using them to better understand learning settings.

Recently, to manage reception of skills and competences, many learning products were introduced and supported by relevant technologies, which were not integrated in the LMS. Due to the lack of adequate institutional resources, the support for many learning activities was not sufficient. To compensate the isolation of the resources, which result from the lack of face-to-face interaction with educators, the students manage and complete their learning activities in a self-directed manner. It is known that Google serves as the most used e-learning platform in such a context where students struggle to find relevant and personalised resources and support. This trend is counterproductive for both the institutions and the learners. The institutions are undermining their reputation and their attractiveness by losing the control of the resources and their usage. The learners, especially the ones with little social network and limited digital literacy, waste their time in unproductive search rather than focusing on productive activities.

1.2.4 Resume

1. This section underlines the novel educational solutions based on the e-learning techniques, effective assessment approaches, and progressive learning management systems which bring alternatives to the problem issues and prevent their negative impacts.

2. The benefits of virtual and remote laboratories concern their impact on students and an important role they play in the educational process, particularly in distance education, learning-on-the-job, suitability for sharing by many institutions, and saving much time and money.

3. The key features of the new assessment methods provide an active participation of learners in the assessment of their own performance and the

development of reflective thinking that stimulate a learner and provide the actual feedback.

4. Thanks to web-based learning management systems and social media services, the university management is becoming more convenient, effective, and efficient, thus enabling staff and learners to control better the learning process and the skill acquisition.

1.3 Management of Learning Electronics and Power Electronics

1.3.1 Procedural model of an educational system

Like in the most approaches, the curricula management starts with identifying the courses and requirements which, when successfully completed, should produce the graduates who possess the knowledge and ability to function as engineers. The institution develops the curricula based on the perception of its expert faculty, who often cannot possess the first-hand information about an application area and the market needs. As the market has grown, the customers demand higher levels of knowledge, and the graduates' competition has mandated more flexibility and efficiency. An educational system must effectively bridge a great number of disciplines and should apply to modern industrial and commercial requirements.

To analyse and design an educational process, different approaches may be used. The *procedural models* mostly applied to this aim are based on an algorithmic decomposition of the solved problem by the consecutive determining of evident formalised tasks [9801], [9807]. Every problem is fitted by its own *procedure*, which describes the actions upon the objects. Such «share and rule» decomposition assumes breaking up the problem into the set of tasks which resolve results in the solution of the whole problem. Thanks to the logical segmentation, numerous planning, management, and documenting processes can be arranged in this way [8602].

The algorithmic procedural approach serves as a suitable tool for the top-down analysis and design. An algorithm is a set of rules that appoints the final sequence of the time-determining actions. Therefore, the procedural decomposition may be represented as a kind of the decision tree an example of which is given in Figure 1.1. This diagram of a learning process includes the root, branches, nodes, and leaves. The leaves exhibit the particular learning instruments whereas the nodes involve the normative documents, and the branches display their connections. Drooping from the root to a leaf along some trajectory is a technique for possible solution of the problems in educational planning.

To implement the procedural approach, a designer has to understand fully the contents of the whole system, its structure, the principle of operation and behaviour [J. Liebowitz]. In a word, the problem is to be analysed carefully before solving it. While the algorithm is not built, it is not possible to start the document development and execution, otherwise, the system does not fit the design requirements [9601],

[0610]. Violation of this rule complicates the planning of the teaching activity and often arouses errors. This is an important peculiarity and drawback of the procedural approach.

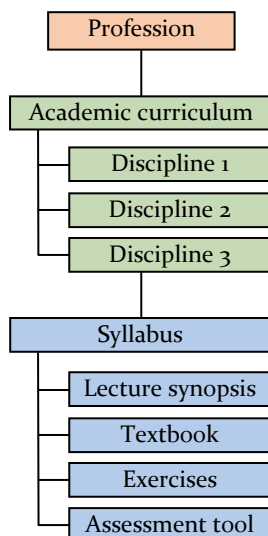


Figure 1.1. Block-diagram of functional decomposition of institutional performance

It becomes very difficult to describe complex systems using only procedural techniques. The reason lies in the nature of a modelled object because any procedural model implies a one-sided, incomplete, and prejudiced glance on the original. In reality, this glance alters with the designer's experience and professionalism. Above all, an object itself is in progress gradually, thus inciting to evolve the model adequately.

1.3.2 Object model of an educational system

In this study, object decomposition is proposed instead of the procedural approach [Z10]. To evaluate the procedural model from the object viewpoint, pick out the main components of an educational system. Let curricula, syllabi, lectures, exercises, etc. be elementary *objects* of the model. The academic process is called to form the skills and ideas through such objects, thus providing the solution of the professional problems. The role of procedures here is to link the objects (Figure 1.2).

Also, the objects and procedures of the model shown in Figure 1.2 can be distributed in space (Figure 1.3) and in time (Figure 1.4).

Let a *syllabus* be the model of a discipline where the professional concepts are shared among the studies. In turn, let a *study* be the model that describes and defines

the concepts. Traditionally, the theoretical and practical studies are discerned. Particularly, a lecture serves as the model of the theoretical (logical, mathematical, pragmatic, or philosophic) concept conclusion, a laboratory practicum provides the experimental deduction of some concept through other ones, a course work is a model of the self-dependent generation of the new concepts, etc.

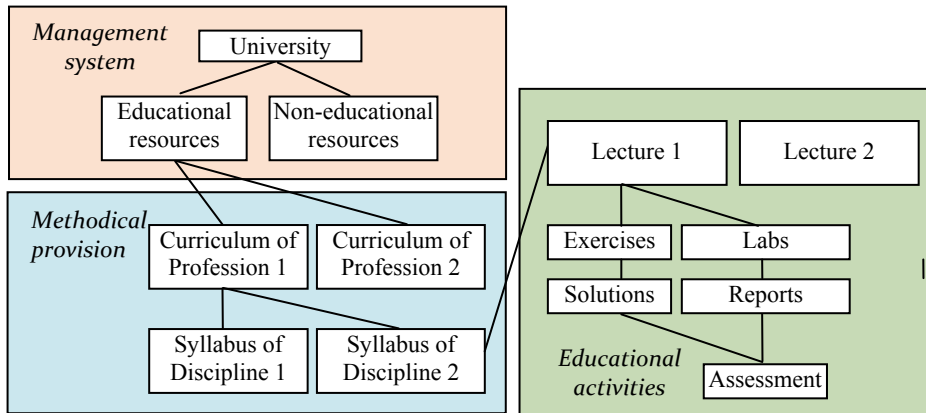


Figure 1.2. Object decomposition of an educational process

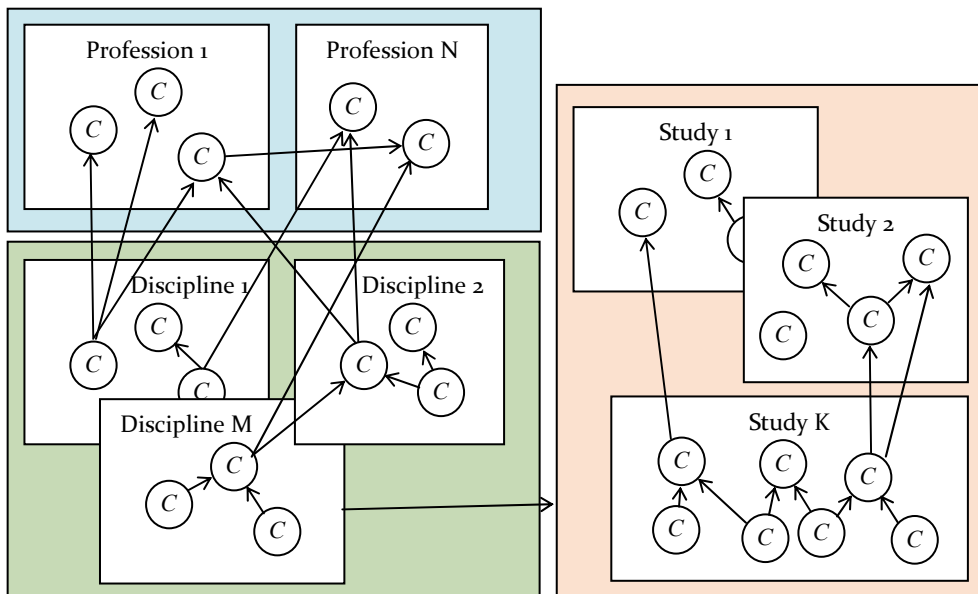


Figure 1.3. Object interaction of professions

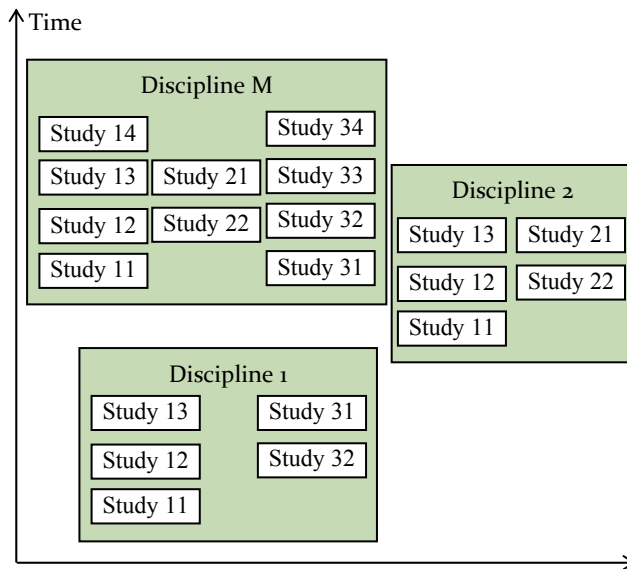


Figure 1.4. Object sequence of a profession

Let a *concept* be the elementary unit of knowledge composed of the unique combination of characteristics and defined within the particular disciplines of the curriculum. A *discipline* serves as the source of ideas about the particular knowledge domain for both a teacher and a learner.

The proposed object approach has a number of benefits upon the above-discussed procedural approach has. First, unlike the procedural methodology which arouses the intersections of the learning processes, here the protection from the concept repetition in various disciplines and studies is arranged. This results in a decrease of the number of links and the full learning path. Second, an alteration of process data does not call a change of other processes now. Thus, the data change cannot provoke violation in the study course. Therefore, the «task selectivity» and the mixing of the task order are avoided.

1.3.3 Flowchart of TUT curricula in Electronics and Power Electronics

TUT acts within the EU higher education and research space. In terms of basic activities, infrastructure and values, TUT is among the fast advancing European universities of technology.

At TUT, the volume of studies set forth in the curricula is based on the European Credit Points (ECP) according to the recommendations of the Bologna meeting of 1999 [0602], [WL09]. Studies comprise classroom, laboratory practices and exercises. All the curricula in the field of power engineering, including the bachelor's and master's degree curricula, were accredited by the international

committee in 2006. The nominal study period is established by the curriculum based on the nominal study load.

The curricula of the bachelor's and master's specialities Electrical Drives and Power Electronics (AAAB02) and (AAAM02) are designed to meet the requirements for employees working in the field. The bachelor's degree graduates need in an interdisciplinary knowledge for applying the essential subjects to manufacturing, assembling, selling, and offering the high quality service for customers. Against this background, the contents of the bachelor's curricula are based on mathematics, physics, computer engineering, electromechanical engineering, electrical engineering, material technology, electrical drives, electronics and power electronics to understand, to assemble, to operate the products, and to measure and influence their performance. The master's level graduates require knowledge in the design and tuning of the electromechanical systems. Therefore, they obtain advanced knowledge in automation and control systems, computer studies, advanced electrical drives, advanced power electronics, manufacturing technologies, maintenance, and service.

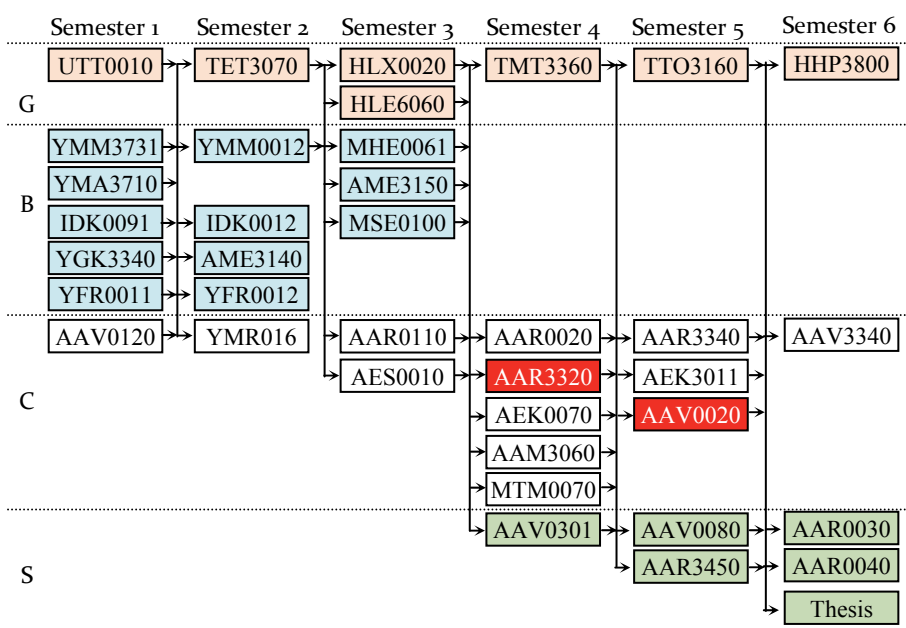


Figure 1.5. Flowchart of the bachelor's study curriculum AAAB02

A curriculum may be envisaged as a flowchart where the particular disciplines are linked by the knowledge flow from one course to another. In this format, the bachelor's study curriculum is shown in Figure 1.5 and the master's study curriculum in Figure 1.6. The disciplines are combined into the general (G), basic (B), core (C), and special (S) groups of study.

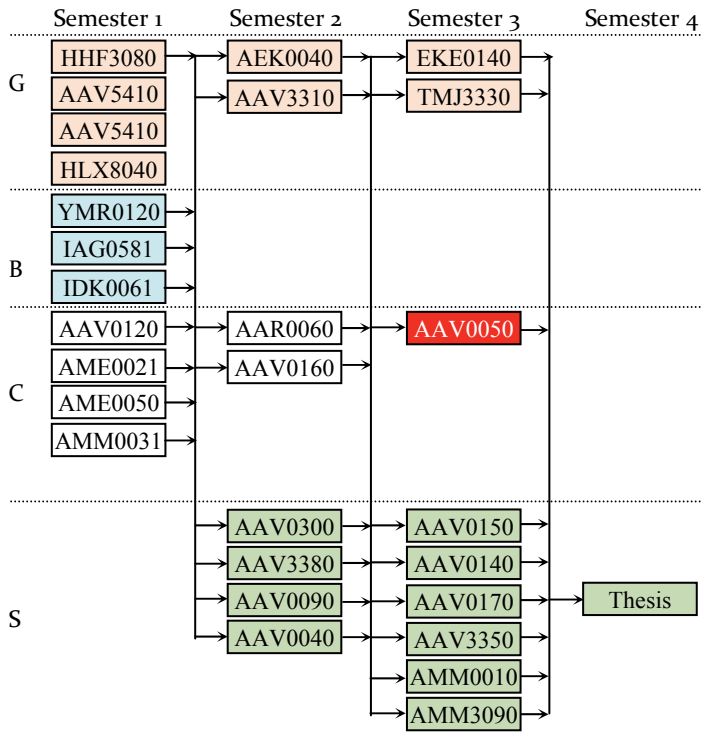


Figure 1.6. Flowchart of the master's study curriculum AAMB02

1.3.4 Drawbacks of the traditional approaches

Many of today's TUT departments train graduates whose relevance as well as quality becomes unacceptable to the organisations that outsource their labour needs from the university. A study of the above given curricula provides useful information about the following reasons of these phenomena resulting from the procedural approach to the curricula organisation:

- the grouping principle of the disciplines is often ungrounded as the groups G, B, C, S have neither significant difference nor strong influence on the learning process
- the contents of different courses are poorly intercommunicated, therefore the interdisciplinary links may be used or disregarded as dependent of the course syllabi
- substantial repetition of course contents in different disciplines often occurs

- the structure of the curricula is rigid and unsuitable for changes due to the fixed volume of the disciplines and their invariable positions in the curricula

Particularly, the disciplines Numerical Methods in Electrotechnics (YMR0160) and Introduction to Power Engineering (AAV0120) are lectured before Electrical Engineering (AME), Physics (YFR), and Mathematics (YMM). Electronics (AAR3320), Electrical Machines (AMM3060), and Materials Engineering (MTM0070) forego Electrical Materials (AEK0070). Work Practice (AAV0301) precedes Risk and Safety (TMT3360), High Voltage Engineering (AEK3011) foreruns Electrical Apparatus (AAR3340) whereas Basics of Measurement Engineering (AAR3450) are learned at the end of bachelor's training. Thus, the traditional curricula management is inappropriate both for educators and students who need continuous enhancing of their professional knowledge.

To overcome such restrictions, some approaches have been developed in the worldwide educational practice. A "curriculum container system" was proposed in [0508]. This five-level structure with the curriculum, unit, task, episode, and element levels is rather complex for teachers who should follow it carefully along with the learning process. The teacher's activity is restricted here by the curriculum "aggregates", thus any time when somebody wants to change a learning trajectory, the curriculum is to be modified. Another widespread direction in the curricula development, navigation, and validation is known as a "concept mapping" [WL18]. The concept maps are used in mechanical, chemical, and computer engineering across a wide range of educational applications [0705]. Unfortunately, they concern only one possible venue in clarifying the student's perception of the field of study, venturing through a simple visual presentation of the curriculum components. One more tool for the study design and improvement is a knowledge representative "conceptual graph" [0707], though this approach elaborates the concept mapping technique having stronger influence on the syllabi content rather than on the curriculum topology.

Therefore, redefining the structure and the contents of a curriculum is not a simple task given the fact that all the traditional formats present the outcomes of the evolutionary developed education. Actually, in all the described systems the changes in curricula are conducted by addition, deletion, and, sometimes, contents modification of the courses. The relationship between courses is often tenuous with the exception of what is termed as a pre-requisite [0811]. Any modification of these types of curricula tends to crowd the learning period and heavily depends on the faculty resources. This prioritisation usually results in slow, but definitely compressed contents. It narrows focus, and, in certain cases, discourages creativity.

Following the above analysis of the promoted innovative setups and practices of educational systems, the current research proposes a novel approach to the curricula development in the fields of electronics and power electronics. The aim is to

increase the level of the specialists' preparing and to raise the quality and efficiency of teaching and training.

1.3.5 Resume

1. Different models of educational systems were compared in this section, including the procedural approach, the object approach, and the flowchart.

2. The most popular procedural model of an educational system used for the top-down analysis requires full information about the system, its structure, the principle of operation and behaviour from the designer, thus complicating the planning of the teaching activity.

3. Launching the object model, the most important learning objects, such as concepts, disciplines, syllabi, and studies, were introduced, including their distribution in space and time, as well as their procedural interconnection needed for the system analysis and synthesis.

4. The proposed flowchart revealed serious shortcomings of the traditional curricula, such as inappropriate grouping principle of the disciplines, poor intercommunication and repeating of the course contents, and the rigid structure of the curricula unsuitable for changes due to the fixed volume of the disciplines and their invariable positions in the curricula.

1.4 Research of Students' Expectations and Opinions

1.4.1 Survey organisation

In general, student population enrolment is mostly composed of young adults who bring to the university the knowledge, skills, attitudes, study habits, motivations, and interests acquired in secondary education and from other cultural experiences. Their expectations frequently lack the effect that is required to help them achieve academic success within the prescribed time. It concerns the disciplines discussed above. Therefore, it is the teacher's responsibility to encourage students in building deep knowledge for rich, diverse, motivating and demanding strategies to be adopted from a cognitive point of view.

To find the most effective ways of educational improvements, TUT students were surveyed [Z17]. The major preferences and expectations of 165 students in the 1st, 4th, 5th, 7th and 9th academic semesters were studied by the polls developed by the author. As distinct from the traditional questionnaires, the students were asked to complete a kit of statements using one of the three options. The statements concerned the following three important problems:

- Do the students need higher education in their chosen speciality?
- Do they acquire the required volume of knowledge in the university?
- Do they have a possibility to become specialists in their field?

One part of these statements was evidently directed to finding out the respondents' opinions regarding the given questions, whereas the second one implicitly expanded the same opinions. The results of these polls were presented and discussed in [Z17] thereupon they were used in the design of the novel learning environment.

1.4.2 Students' expectations, requirements, and possibilities

To solve the first issue, our interest was in the reasons of a student's choice of his/her future profession and to what extent of determination he/she is ready to domesticate it. The evident statement was expressed as:

I selected my future speciality, firstly considering...
my possibility to learn well
ease of the student life
satisfaction from an employment following completion of my studies

The implicit statements were given in the following form:

- Such school is good which benefits from...
learning process
session output
employment following the high school graduation
- I would like...
to learn everything the curriculum assigns
to be helped in learning everything I wish
to obtain the diploma independent of my study results
- After my study completion, I would like...
to have assured employment that depends on my grade
to have assured employment independent of my study results, with possible turning away in the case of my professional incapacity
to select an employment myself, with possible turning away in the case of my professional incapacity
- I would like...
to complete my study and start employment as fast as possible
to study as long as possible
to complete my study and start employment within the prescribed time
- I would like...
to start employment as early as possible with lifelong learning following
to complete fully my study, and only then start my career
to retrain and change my speciality periodically
- The longer I learn...

the higher are my hopes to become a highly qualified specialist
the lower are my hopes to become a highly qualified specialist
the more I urge upon the incorrect speciality selected

The second group of statements concerned the student's complacency by learning and his/her readiness to improve the study process. An evident statement of this group is the following:

- I think university training should be...
more general and theoretical than presently
more purposeful and applied than presently
just like now

This statement was supplemented by the implicit variants, such as:

- Having a choice, I would prefer...
traditional teaching where a student strictly follows his/her teacher
active learning where a teacher answers the student's requests
to follow the lead of the majority
- I think regular testing...
helps students to learn successfully
draws students away from successful learning
does not affect student progress
- I like the slogan...
«Heavy in learning – easy in battle»
«Bad student cannot turn into good specialist»
«No weak students – there are weak teachers»

Next, focus was on the students' opinion regarding their potential possibilities and their evaluation of the time, staff, and material resources to learn:

- I prefer...
to devote the maximum of my time to learning
to devote the maximum of my time to the rest
to share strictly between the rest and learning times
- I think the majority of teachers...
pay too little attention to a student
devote too much time to particular students in prejudice of the study
volume
pay enough attention to students
- The longer I learn...
the harder my learning progresses
the easier my learning progresses
the more I am convinced that my learning does not progress

- The longer I learn...
the easier it is to remember large study volumes
the harder it is to remember large study volumes
the lower my efforts are to remember study material
- The longer I learn...
the higher is my evaluation of the erudition of the majority of my instructors
the lower is my evaluation of the erudition of the majority of my instructors
the stronger is my opinion that the learning outcome is in weak dependence on the instructors
- The longer I learn...
the higher is my evaluation of the laboratory capacity of my institution
the lower is my evaluation of the laboratory capacity of my institution
the stronger is my opinion that the learning outcome is in weak dependence on the labs capacity

1.4.3 Analysis of the survey

As a result of the survey some important conclusions were drawn. It was found that about 90 % of the entrants choose their future speciality independent of the leaning difficulty or assessment scores. Only 10 % would like to be retrained and change their profession in the future. It is notable that 68 % would like to get help from the university in learning everything they wish. Only 4 % agree to obtain the diploma and 19 % need in assured employment independent of their study results. Only 8 % of the students are ready to extend studies whereas the remaining wish to start a career sooner. 67 % of those surveyed believe that the university will train them to be highly qualified specialists.

It is noteworthy that almost none of the students thought that university training should be more general and theoretical than at present. On the contrary, 76 % are seeking to acquire the most purposeful and applied education. About 2/3 of the students share effectively between their rest time and learning time. 68 % of the respondents would like to implement active learning as the prospective method of education though less than half of them have their own experience in this approach. 65 % accept regular testing as a useful assessment method. 68 % consider the learners are the most responsible participants of the learning process and agree with the slogans «Heavy in learning – easy in battle» or «Bad student cannot turn into good specialist». Half of them find that the obtained knowledge is in weak dependence on the instructors.

It seems distinctive that 54 % of the examined learners consider that their teachers have enough time and pay enough attention to students. Only 17 % pointed out the low capacity of the institutional laboratory equipment. 39 % found the current progress in their knowledge acquisition.

1.4.4 Resume

1. This section describes the survey of the learning preferences and expectations of 165 students which thereupon were used in the design of the novel learning environment.

2. The questionnaire developed and conducted by the author concerned the following three important problems: if the students need higher education in their chosen speciality, if they acquire the required volume of knowledge in the university, and if they have a possibility to become specialists in their field.

3. As a result of the survey it was found that most of the entrants consciously choose the future speciality and would like to get help from the university in learning everything they wish, believing the university will train them to be highly qualified specialists.

4. Almost none of the examined students thought that university training should be more general and theoretical than at present whereas majority of them are seeking to acquire the most purposeful and applied education.

1.5 Summary of Chapter 1

The analysis of the promoted innovative setups and practices of educational systems revealed that the engineering community suffers the necessity to develop new education technologies based on the Bologna Declaration and an active learning approach that moves the responsibility of learning on learners by shifting from time-based to achievement-based education.

Most prospective novel educational solutions found in the study relate to the e-learning techniques, effective assessment methodologies, and progressive learning management systems which provide the development of reflective thinking, thus enabling staff and students to manage better the learning process and the skill acquisition.

Launching the object model, the most important learning objects were introduced in this chapter, such as concepts, disciplines, syllabi, and studies, an analysis of which revealed serious shortcomings of the traditional curricula including inappropriate grouping principle of the disciplines, poor intercommunication and repeating of the course contents, and the rigid structure of the curricula unsuitable for changes.

The survey of the students' learning preferences and expectations arranged by the author exposed that the majority of learners are seeking to acquire the most purposeful and applied education using active learning approaches and effective training possibilities.

CHAPTER 2. DEVELOPMENT OF KNOWLEDGE MODELS ON THE BASE OF EDUCATIONAL THESAURI

2.1 Analysis of the Traditional Thesauri

2.1.1 Concepts and thesauri

Through experience and education people appreciate the surrounding world. Every educational system is oriented on the increase of an individual's knowledge that includes information, facts, descriptions, and skills. Schooling, study, observation, and practice supply an individual with concepts [Z28]. All the concepts may be divided into the known and unknown ones. Let us call the concepts given beyond an academic syllabus as *outside concepts*. A learner knows the meaning of the outside concepts at the ongoing stage of a course. During the educational process a learner crosses a succession of knowledge levels (courses), thus obtaining new conceptual understanding of the universe. As a student passes from one academic course to another, a balance of the known and unknown concepts changes gradually. Next, call the concept the meaning of which is described by the current schooling as a *defined concept*. Let us call the entries earlier introduced in the course and used to explain a defined concept as *parents* and the entries produced from the defined concepts as *kids* (Figure 2.1 (a)).

It is suitable to evaluate the knowledge level of both a society and its individuals by a *thesaurus*. According to [9701], a thesaurus represents a compendium of a body of knowledge with the structured controlled relationship of concepts within an application area. In the practice of bibliography, the thesauri are developed using the standards ISO 2788 and ISO 5964. In most cases, the “universal” encyclopaedias, numerous dictionaries and glossaries can be referred to as compendiums of all human knowledge, both known and unknown for individuals. Many thesauri types exist, such as encyclopaedic and explanatory dictionaries, professional glossaries, reference books, etc. Some of them belong to the online tools, the most powerful of which are Wikipedia.org, Thesaurus.com, Ask.com, Thefreedictionary.com, Visualthesaurus.com, etc. The online glossary Electropedia.org [WL11] covers explanations of the concepts relevant to electrical engineering.

The knowledge level of an individual may be estimated by the personal thesaurus presenting the collection of known concepts that concerns some delimited field of the individual's interest.

Every thesaurus entry represents an article devoted to a separate concept, including its *term* and *definition* (Fig. 2.1 (b)). All the thesaurus articles are directly and indirectly connected with each other. Generally, the direct links have the alphabetic and thematic nature of the concept terms. The indirect links are implemented throughout the concept definitions which expose a concept by dozens of other terms. A degree of the conceptual appreciation from the thesaurus depends

on the learner knowledge of the concepts used in a definition. The presence of unknown components impedes progress in learning.

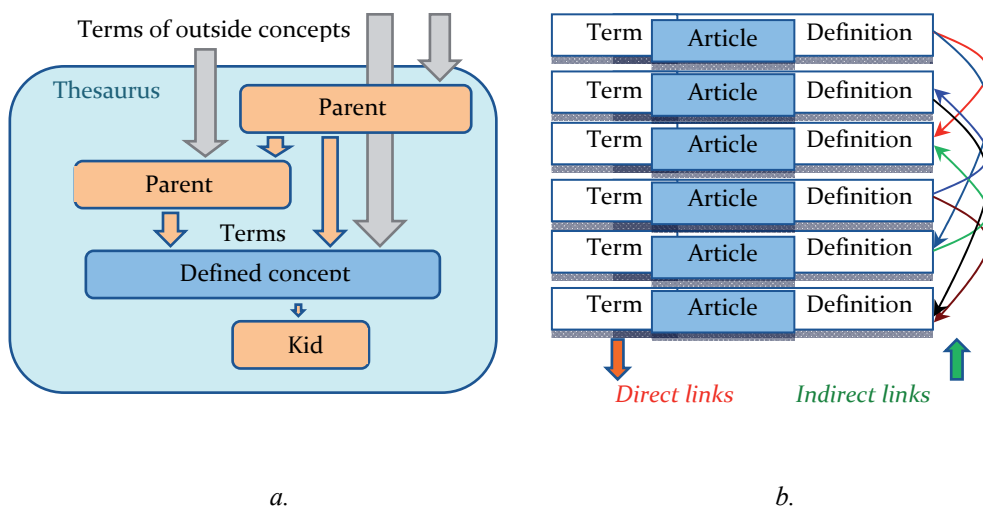


Figure 2.1. Concepts (a) and their arrangement in a thesaurus (b)

Numerous methods have been developed for the thesaurus presentation [1012]. Traditional offline encyclopaedic and explanatory dictionaries have the article structure. To develop and explore them, the theory of syntax [6501] is used. Separate processing of the terms and definitions has a higher effect. Numerous database technologies and list handling methods along with matrix approaches are applied to study the separated terms [8602]. As well, many treelike algorithms were designed to optimise and enhance the entries [9702].

Using the graph theory [0803], an information model of the thesaurus may be represented by N-ary homogenous *semantic network* [0004]. A graph in this context refers to a collection of vertices (nodes) and a collection of edges (arcs) that connect pairs of vertices. The size of the graph is equal to the number of vertices. The number of tail endpoints of a vertex (outdegree) is exactly one concept. The number of head endpoints adjacent to a node (indegree) is equal to the parent number. In contrast to the directed trees having only one path between any couple of adjacent vertices, the path between any pair of vertices of the described graph involves the kit of all adjacent vertices whereas its length is measured by the number of connecting edges.

In Figure 2.2, a fragment of a thesaurus is represented by the semantic network, the size of which is 10. Vertex 1 serves as a tree root whereas vertex 10 is a leaf. The indegree of vertices 6, 7 and 10 is 2; the indegree of vertices 2, 3, 4, 5, 8 and 9 is 1, and the indegree of the root is 0. The concepts of the appropriate vertices 2, 3 and 4 are defined through the root concept. The concept 5 is expressed by 2, the concept 6 – by 3 and 4, the concept 7 – by 1 and 6, the concept 8 – by 5, the concept

9 – by 7, and the concept 10 – by 8 and 9. The path from the root 1 to the leaf 10 involves all the vertices, thus its length is equal to 12. The path from 7 to 8 runs through the vertices 1, 2, 3, 4, 5 and 6, and its length is equal to 9.

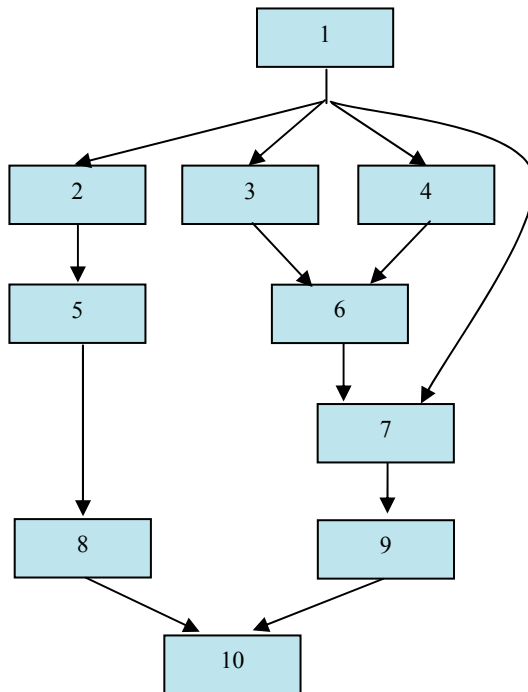


Figure 2.2. Semantic network of a thesaurus

An instrument suitable to analyse such networks is an *adjacency matrix* i.e. a square matrix, the order of which is equal to the number of the graph vertices. The acyclic nature of the graph is marked here by the zeros along the leading diagonal whereas the graph connectivity and directivity are labelled by the unit off-diagonal entries in each line.

Common operations on the thesaurus graph are as follows:

- searching for an item
- adding a new item at a certain position
- deleting an item
- enumerating all the items
- tree traversal along the specific path

Generally, a modified family tree, called as a *pedigree chart* [9804], may successfully represent conceptual relationships, starting from the root (ancestor's) and ending by the leaf (descendant's) concepts. Unlike a conventional family tree

structure, the number of incoming branches for a thesaurus tree node is not limited by the couple of parents whereas each node has only one outgoing branch.

2.1.2 Case study in Electronics

As an example, let us analyse the definition of the concept “*electronics*” from the viewpoint of learning suitability and comprehension.

According to Wikipedia.org, “*Electronics* is a branch of [science](#), [engineering](#) and [technology](#) that deals with [electrical circuits](#) involving [active electrical components](#), such as [vacuum tubes](#), [transistors](#), [diodes](#) and [integrated circuits](#), and associated [passive interconnection technologies](#)”. Let [science](#), [engineering](#) and [technology](#) be the outside concepts. All the other concepts used in the definition, such as [electrical circuits](#), [active electrical components](#), [vacuum tubes](#), [transistors](#), [diodes](#), [integrated circuits](#), and [passive interconnection technologies](#), undoubtedly belong to electronics. Therefore, a student who has decided to enrol in electronics cannot understand its meaning until he/she knows the parents. We proceed through the link [active electrical component](#) to understand its meaning. Here, Wikipedia conducts you over the parent [passivity](#) which is opposite to the active component: “A component that is not [passive](#) is called an [active component](#)”. Following the next link, a learner recognises an electronic component as “a basic [electronic element](#)” and, using the latter link, returns to “*electronics*”.

Replace Wikipedia.org by Visualthesaurus.com to solve the same problem of “*electronics*” comprehension. This powerful graphical thesaurus defines “*electronics*” as “a brunch of [physics](#) that deals with [emission](#) and effects of [electrons](#) and with the use of [electronic devices](#)”. Let [physics](#), [emission](#), and [electrons](#) be the outside concepts introduced earlier in physics. Therefore, to understand “*electronics*”, the student must know the meaning of an [electronic device](#). Following the link, you find out that “Electronic device is a device that accomplishes its purpose [electronically](#). What does [electronically](#) mean? The thesaurus answers: “[Electronically](#) – by [electronic](#) means” and finally returns the learner to “*electronics*”.

Finally, in Electropedia.org: “*Electronics* is a branch of [science](#) and [technology](#) dealing with the motion of [charge carriers](#) in [vacuum](#), [gas](#) or [semiconductor](#), the resulting electric [conduction phenomena](#), and their applications”. In turn, you find out that the [charge carrier](#) is “a particle, such as an [electron](#) or a [hole](#), having non-zero electric [charge](#)”. And finally, “[Hole](#) is a vacancy behaving like a [carrier](#) of one positive elementary [charge](#)”. Thus, the circle has closed up!

Conclusions based on the analysis:

1. In most thesauri, *concepts are defined through their parts* like this one: “House is a building consisting of windows, doors, roof, etc”. Thus, a reader cannot recognise the concept until he/she understands its parts.

2. The popular thesauri are unprotected from the *recursion* at which the concept in question is indirectly defined through itself. For instance: “A book is a set of pages”. “A page is a part of the book”.
3. Often, *neglecting* is used in a definition, i.e. a concept is defined through the neglecting concept. For instance: “Truth is not False”. Thus, to understand the concept, a user must recognise the opposite concept.
4. Many thesauri are *indifferent to the synonyms*. Particularly, many articles in Wikipedia.org explain the sense of the same concepts independent of each other.
5. Generally, the thesauri do *not support redefining* of the concepts. Their definitions are absolute and cannot be adapted to the reader’s knowledge level.
6. As the number of parents is not restricted, an appreciation of the sense for the defined concept can take much time and effort.

Hence, the traditional thesauri do not meet learners’ expectations and prevent success in learning. Therefore, a novel approach to the thesaurus design is required.

2.1.3 Principles of arrangement of educational thesauri

The present section focuses on the development of a new tool, namely an *educational thesaurus* (ET) [Z03], [Z09]. Contrary to other thesaurus types, it is intended primarily for learning. Every course studies the concepts in a specific context, giving them distinctive meanings that may deviate from the meaning the same words have in other contexts and in everyday language. A properly organised ET of a discipline is described by the finite connected directed acyclic graph (so called undirected tree) whereas a speciality thesaurus looks like a forest of such trees. Taking into account this target, the ET structure and the definition part require a unique arrangement explained in this section. Following the analysis of the ordinary thesauri shortcomings from the viewpoint of educational purposes, new principles of the ET arrangement are proposed here. Then, the methods of thesaurus filling and ranking are developed and an example of their application is given. The results of the ET implementation are presented in the final part of the chapter.

Assume an ET comprises m entries. Describe each of m concepts CON_i by an i -th entry with the following components:

$$CON_i = \{i, Term_i, D_i(T_{i1}...T_{ip})\}, \quad (2.1)$$

where $i = 1...m$, $T_i \neq Term_i$, $p < m$. Here, i is an index, $Term$ is the term which titles the concept, D is the definition of the defined concept, and T are the terms of the parents used in the definition of CON_i .

Let us formulate now the main principles of ET arrangement that help to overcome the drawbacks of the traditional thesauri from the educational viewpoint. Shortly, they are as follows:

- from known to unknown
- from simple to complex
- step by step (no recursion, no repetition)
- redefinitions and synonyms are welcome

The strong statement of these principles sounds as follows [Z30]:

Principle A. In the definitions $D_i(T_{i1}...T_{ip})$, the application focus and/or the main operation principle of the defined ET concepts must be outlined. It is prohibited to explain thesaurus concepts through their parts and opposite concepts. This means the parents are to be introduced into the thesaurus before the defined concept. Mathematically, a properly designed ET should be presented by the left-triangular matrix of terms.

Principle B. The first concept CON_1 is to be the heading of the current course defined through the terms foregoing this course ($p = 0$). This will result in the learners' appreciation of the course goals and requirements before enrolment. If the body of terms is presented by the list, relational database or matrix, the term of the starting concept will be the first ET line or row,

$$CON_1 = \{1, \text{Course title}, D_1(0)\}. \quad (2.2)$$

If the thesaurus is drawn by the tree, the course heading will occupy the tree root that is the node without the ongoing branches. For instance, for the first entry of the course "Electronics" the following definition of "electronics" meets the proposed principles: "Electronics is a field of science, engineering and technology dealing with semiconductors and, rarely, with vacuum tubes". All the parents of this definition are the terms foregoing the course. Neither parts nor the opposite concepts are used. Other examples will be given below.

Principle C. It is reasonable to restrict the number of parents by two or three ($p < 4$). The definitions based on the greater number of the parents require much time and effort for understanding.

Principle D. As the synonyms are the usual ET entries, all the synonyms must be referenced to the uniform definition within the thesaurus.

Principle E. ET must be accomplished with the tools that prevent recursion along with the thesaurus filling. At the same time, synonyms are not the same as repetition. Hence, the ET must be accomplished with the tools that prevent repetition during the thesaurus preparation.

Principle F. Redefining of the concepts is the normal situation in education. While the first definition is simple and short, the following ones may be more complex and detailed as they are based on the new concepts introduced throughout the course duration.

2.1.4 Resume

1. The thesaurus model is offered in this section which links the defined concepts with the outside concepts given beyond an academic syllabus, the parents earlier introduced in the course and used to explain a defined concept, and the kids produced from the defined concepts.

2. Along with the theory of syntax, database technologies, list handling and matrix methods, a modified family tree, called as a pedigree chart, was introduced in this section as a successful tool for representing and exploring the thesaurus conceptual relationships.

3. Using this apparatus it was shown that the traditional thesauri do not meet learners' expectations and prevent success in learning, therefore the novel approach to the thesaurus design is welcome.

4. As a result, six principles of an educational thesauri arrangement were grounded in this section, namely an application focus, a term of the first concept, a parent number restriction, a synonyms definition, a recursion protection, and a concept redefining.

2.2 Algorithmization of Thesaurus Assembling

2.2.1 Class-built model of an educational thesaurus

To implement the above described semantic network as the software, use an object-oriented approach [0615] as an effective method of the system development [Z10]. This paradigm is based on the classes of interacted objects. A *class* is the generalised model of a group of similar objects, the characteristics of which are presented by the properties and the behaviour of which is described by the procedural patterns without concrete values [9301]. The class properties and procedures are called *members*. Each system object is a representative of a class. The object characteristics and behaviour do not depend on other classes, thus it is not required to know other classes to understand the particular class logic. An association of the property and behaviour description in the class is the main distinction of the object-oriented approach from the procedural method where the properties are separated from the executed procedures.

In the class-built model shown in Figure 2.3, a class *Thesaurus* plays the role of the abstract generic class. The members of the class are as follows: the public property *Term* which names objects and the abstract procedures *Get()* to obtain the required object data, *Find()* to find an object, *Put()* to place an object into the thesaurus, and *Del()* to delete an object from the thesaurus.

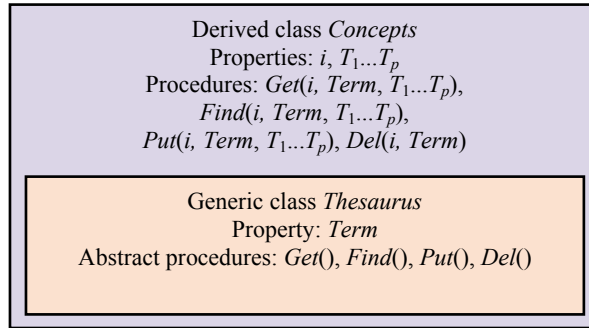


Figure 2.3. Class-built model of an ET

Based on the class *Thesaurus*, the derived class *Concepts* is established. In addition to the inherited property *Term*, it involves a property *i*, which designates the starting time of the concept definition. Traditionally, the time is measured by the academic weeks though other, more flexible units may be used instead. Other class components are the private properties $T_1...T_p$ that identify the parents. The behaviour of a concept is described by the renewed procedures. The procedure $Get(i, Term, T_1...T_p)$ acquires the term and the parents of a new object. The procedure $Find(i, Term, T_1...T_p)$ searches a concept in the thesaurus whereas $Put(i, Term, T_1...T_p)$ places it into the thesaurus along with *i* calculation, and $Del(i, Term)$ erases a useless concept.

The main problems with respect to adding the concepts to the thesaurus are to protect the ET from repetition and to provide the concept redefining. The system must distinguish the particular concept as either a new or an existing one. The concept identified as a new one is to be inserted into the thesaurus whereas the existing concept must be denied. An important task of this process is to measure a degree of equivalence between the presented and available concepts. In fact, the system should search and measure a portion of information in the introduced concept. To this aim, the *parsing* is required. The parsing method proposed in the N. Chomsky generative linguistics [6501] may be implemented as follows.

First, to check the concept integrity, all the parents that define the presented concept are included in the search key. If this step fails, the content is divided into the groups having the particular keys T_{ip} , which may be divided again until the nearest concept will be found or the search fails. Thus, the search in the thesaurus is described by the following chain of operations:

$$i = Find(Term_i, T_{i1}...T_{ip}) \quad (2.3)$$

$$\text{or } i = Find(Term_i) \quad (2.4)$$

$$\text{or } i = Find(Term_i, T_{i1}) \dots Find(Term_i, T_{i1}...T_{ip-1}) \quad (2.5)$$

Using the class-built model, the process of ET assembling may be described in the following manner.

The procedure *Get* acquires new concepts. The procedure *Find* searches for the concept term in the thesaurus and returns the properties i and $T_1...T_p$ of the concept detected. Next, this result is used by the procedure *Put*, which compares the received variables $T_1...T_p$ with the values given by the procedure *Get*. If the concept is not defined yet, the procedure *Put* will add it into the thesaurus at the earliest timing position i .

On the other hand, the concept may be detected in the thesaurus as an incomplete entry without some components from the list $T_1...T_p$. In this case, the procedure *Put* enters the concept into the thesaurus again (redefines it) and indicates the value i obtained from the detected concept. In addition, the new components of $T_1...T_p$ are placed into the renewed concept. To calculate the time i , the procedure *Find* searches the values i of all parents given by the list $T_1...T_p$. The greatest of the values $i = i_{\max}$ represents the seeking value $i > i_{\max}$ of the renewed concept. In this way, the proposed method protects the thesaurus from the concept repetition and supports conceptual redefining.

Finally, the procedure *Del* erases the obsolete entries.

2.2.2 The problem of assembling a thesaurus

Assembling of the thesaurus is the next problem faced by the thesauri developers [0807], [1007]. This problem concerns mainly the filling, edition, and ranking procedures.

Many sorting algorithms are described in literature, starting from [8602], [9702]. Nevertheless, unlike the simple data list, the key of the thesaurus ranking is an unknown earliest position i at which a defined concept may be introduced into the learner's knowledge area. This parameter should be derived based on the known terms $T_1...T_p$, predetermined the ranged concepts. Unless a designer introduces a concept in time, the concept doubling occurs that complicates conceptual comprehension. First, this draws out the learning period. Second, the professional knowledge structure entangles unreasonably. Additionally, learning loses its clarity and attractiveness.

Let i be a permissible instant to introduce the concept CON_i . Assume CON_i is a defined concept and T_j is a term of a parent from the definition of CON_i , $j = 0...p$, $T_j \in \{T_1, T_m\}$. The defined concept CON_i depends on some parent terms T_j and does not depend on the remaining concepts from m . The greater is i , the later a concept CON_i should be introduced into the learner's knowledge area. The research problem is to find $\min(i)$ that is the minimum possible index of the defined concept CON_i .

In the common case, the body of the thesaurus terms may be represented by the rectangle matrix of m rows and $m+2$ columns shown in Table 2.1, where $w_{jj} \in \{1, 0\}$ are the binary connection weights.

Table 2.1. Thesaurus matrix

i	Term	T_1	T_2	...	T_i	T_{i+1}	...	T_m
1	Term ₁	$w_{1,1}$	$w_{1,2}$	...	$w_{1,j}$	$w_{1,j+1}$	...	$w_{1,m}$
2	Term ₂	$w_{2,1}$	$w_{2,2}$	...	$w_{2,j}$	$w_{2,j+1}$	...	$w_{2,m}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	Term _{i}	$w_{i,1}$	$w_{i,2}$	...	$w_{i,j}$	$w_{i,j+1}$	...	$w_{i,m}$
$i+1$	Term _{$i+1$}	$w_{i+1,1}$	$w_{i+1,2}$	...	$w_{i+1,j}$	$w_{i+1,j+1}$	...	$w_{i+1,m}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
$m-1$	Term _{$m-1$}	$w_{m-1,1}$	$w_{m-1,2}$	...	$w_{m-1,j}$	$w_{m-1,j+1}$	...	$w_{m-1,m}$
m	Term _{m}	$w_{m,1}$	$w_{m,2}$	...	$w_{m,j}$	$w_{m,j+1}$	...	$w_{m,m}$

Consequently, represent an i -th parent group $T_{i1}...T_{ip}$ as follows:

$$T_{i\Sigma} = m(T_j \cdot w_{i,j}) = T_1 \cdot w_{i,1}, T_2 \cdot w_{i,2}, \dots, T_m \cdot w_{i,m}, \quad (2.6)$$

where the universal qualifier $m(T_j \cdot x_{i,j})$ comprises all the parents that define CON_i and j is an index of the matrix column. As the parents were introduced into the curriculum before the defined concept, the terms of the properly designed thesaurus should be described by the left-triangular matrix as follows:

$$\begin{aligned} w_{i,j} &= 0 \text{ when } j \geq i, \\ w_{i,j} &\in \{0, 1\} \text{ when } j < i. \end{aligned} \quad (2.7)$$

In the simplest case, when $j = 0$ (no parents), $i = 0$, which means that all such concepts CON_i may be introduced starting from the beginning of the course. The next task is to rank the remaining concepts CON_i predetermined by the terms T_j of the concepts introduced in the same course.

2.2.3 Ranking algorithm

To rank the thesaurus, which does not meet these conditions, the procedure shown in Figure 2.4 was developed.

Some examples of its operation are given below. They show five particular cases of improvements in the ET.

Case A. The concepts with empty terms are removed from the ET (Table 2.2).

Table 2.2. Removing of the untitled concepts

i	Terms before ranking	Terms after ranking
1	amplification	amplification
2		bridge
3	bridge	

Case B. If the concepts with repetitive terms are found, a request for the concept repair will be generated (Table 2.3).

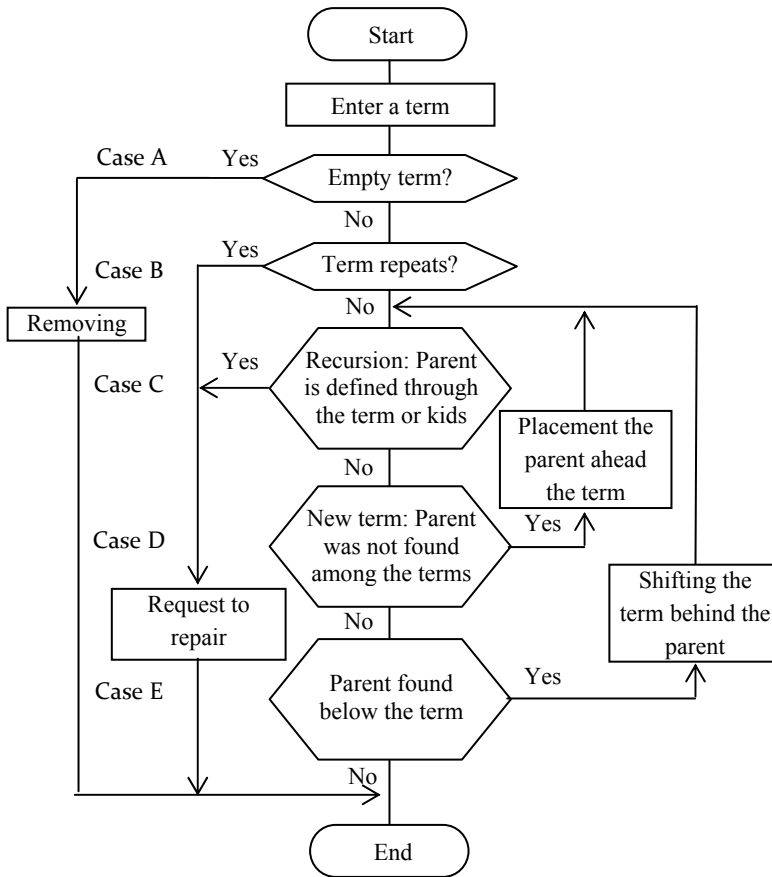


Figure 2.4. Algorithm of the thesaurus ranking

Table 2.3. Repair the concepts with repetitive terms

Terms before ranking	Terms after ranking
amplification	amplification
bridge	bridge
diode	diode
bridge	Repetition! Resolve the problem!

Case C. If the recursion is recognised at which a parent is defined through the term or through the kids of this term, the new request for the concept repair will be generated (Table 2.4).

Table 2.4. Resolving the recursion

Before ranking		After ranking	
Terms	Parents	Terms	Parents
semiconductor	pn-junction	semiconductor	pn-junction
pn-junction	component	pn-junction	component
component	semiconductor	component	Recursion! Resolve the problem!

Case D. If the new term is found, such that its parent does not exist among the terms, the parent term will be placed ahead the defined concept (Table 2.5).

Table 2.5. Entering the new concept

Before ranking		After ranking	
Terms	Parents	Terms	Parents
pn-junction	component	component	
semiconductor	pn-junction	pn-junction	component
		semiconductor	pn-junction

Case E. If the parent is found below the defined term, the term will be moved behind the parent concept (Table 2.6).

Table 2.6. Entering the defined concept after the parent concept

Before ranking		After ranking	
Terms	Parents	Terms	Parents
semiconductor	pn-junction	component	
pn-junction	component	pn-junction	component
component		semiconductor	pn-junction

Taking into account that i is the minimum permissible index of the defined concept, the indexes i of other concepts may further be exchanged using the algorithm proposed above. Thus, the designer obtains an instrument to find the best position for a concept introduction into the course.

2.2.4 Resume

1. An object-oriented approach is used in this section where the *Thesaurus* plays the role of an abstract generic class the members of which include the public property *Term* to identify the objects, and the abstract procedures *Get()* to acquire the object data, *Find()* to search an object, *Put()* to place an object into the thesaurus, and *Del()* to delete an object from the thesaurus.

2. Based on the class *Thesaurus*, the derived class *Concepts* was established with an important index property which designates the starting time of the concept

definition, the properties that identify the parents, and the renewed procedures to acquire the parents of the new object, to search the concepts in the thesaurus, to put them into the thesaurus, and to erase the useless concepts.

3. To assemble the ET without concept repetition along with their possible redefining, the parsing procedure was introduced.

4. Next, the matrix model of the ET was proposed and the ranking algorithm was developed which determines an entered concept as a new or a redefined one and positions it within the thesaurus.

2.3 Concept Tree and User Interface of the Educational Thesaurus

2.3.1 Application example from Electronics

Assume that an unordered ET fragment of the course of Electronics includes some concepts [Z28], like these:

1. **breakdown** – reverse voltage of a *pn junction* where the **Zener effect** occurs
2. **diode** – two-terminal **semiconductor device** serving as a conductor being forward biased and as an insulator being reverse biased
3. *pn junction* – area between *p-type* and *n-type* layers
4. **Schottky diode** – high-frequency **diode** with no depletion layer
5. **intrinsic semiconductor** – single-element semiconductor without *pn junction*
6. **Zener diode** – **diode** designed to operate in the **Zener effect** area
7. **Zener effect** – effect of high current occurring in a **diode** under certain reverse voltage
8. *p-type* – trivalent impurity of an **intrinsic semiconductor**
9. *n-type* – pentavalent impurity of an **intrinsic semiconductor**
10. **tunnel diode** – heavily doped **diode** with a zero **breakdown**
11. **semiconductor device** – electronic device built on **intrinsic semiconductors** with impurities

Here, the blue words present the terms of the new concepts defined within this fragment whereas other words were introduced before this fragment. The defined terms occupy the left side of each definition whereas the parent terms are to the right. The system where every concept, except of the first one, depends on other concepts may be represented by the concept tree (“grove of Academe”). The concept tree of the terms for this fragment is shown in Figure 2.5. The first term of the tree is called a root term, the middle terms are nodes, and the tree ends are known as leaves. The lines connecting the terms are called branches.

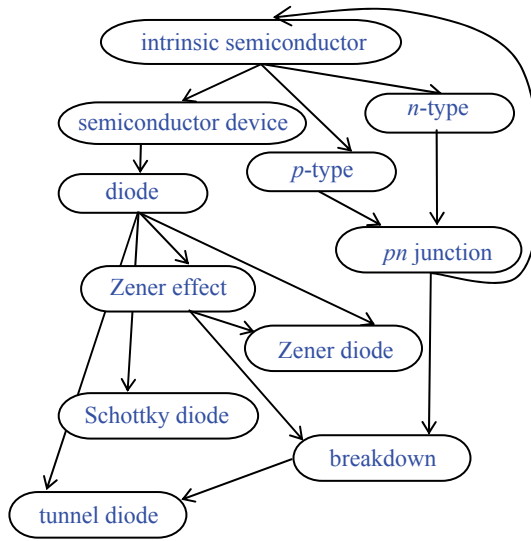


Figure 2.5. Fragment of a concept tree

Table 2.7 represents a table structure of this fragment.

Table 2.7. Fragment of an initial concept table in Electronics

i	Term	T_1	T_2
1	breakdown	Zener effect	pn junction
2	diode	semiconductor device	
3	pn junction	p-type	n-type
4	Schottky diode	diode	
5	intrinsic semiconductor	pn junction	
6	Zener diode	diode	Zener effect
7	Zener effect	diode	
8	p-type	intrinsic semiconductor	
9	n-type	intrinsic semiconductor	
10	tunnel diode	diode	breakdown
11	semiconductor device	intrinsic semiconductor	

Table 2.8 describes the corresponding concept matrix structured in accordance with Table 2.7.

Table 2.8. Fragment of the initial concept matrix in Electronics

<i>i</i>	Term	<i>j</i>										
		1	2	3	4	5	6	7	8	9	10	11
1	breakdown			1				1				
2	diode											1
3	<i>pn</i> junction								1	1		
4	Schottky diode		1									
5	intrinsic semiconductor			1								
6	Zener diode		1					1				
7	Zener effect		1									
8	<i>p</i> -type					1						
9	<i>n</i> -type					1						
10	tunnel diode		1									
11	semiconductor device					1						

An analysis shows the presence of a recursion drawn by the curved link between “*pn* junction” and “intrinsic semiconductor” in Figure 2.5 and an unordered fashion of the fragment. To exclude these shortcomings, the ranking procedure was executed. Table 2.9 displays the finally ranked ET. Here, the new concept “*pn* junction*” was introduced to give the simplified “*pn* junction” description, like this:

pn junction* – area between the semiconductors with mostly positive and negative carriers

Later, “*pn* junction” is redefined in line 5 of Table 10.

Table 2.9. Fragment of the correct concept table in Electronics

<i>i</i>	Term	T_1	T_2
1	<i>pn</i> junction*		
2	intrinsic semiconductor	<i>pn</i> junction*	
3	<i>p</i> -type	intrinsic semiconductor	
4	<i>n</i> -type	intrinsic semiconductor	
5	<i>pn</i> junction	<i>p</i> -type	<i>n</i> -type
6	semiconductor device	intrinsic semiconductor	
7	diode	semiconductor device	
8	Schottky diode	diode	
9	Zener effect	diode	
10	Zener diode	diode	Zener effect
11	breakdown	Zener effect	<i>pn</i> junction
12	tunnel diode	diode	breakdown

Table 2.10 displays the left-triangular matrix of the finally ordered thesaurus.

Table 2.10. Fragment of the correct concept matrix in Electronics

<i>i</i>	Term	<i>j</i>											
		1	2	3	4	5	6	7	8	9	10	11	12
1	pn junction*												
2	intrinsic semiconductor	1											
3	p-type		1										
4	n-type		1										
5	pn junction			1	1								
6	semiconductor device		1										
7	diode						1						
8	Schottky diode							1					
9	Zener effect							1					
10	Zener diode							1		1			
11	breakdown					1				1			
12	tunnel diode							1				1	

2.3.2 Application example from Power Electronics

The list below represents a fragment of a thesaurus for the Power Electronics course [Z23]. It includes short definitions of the following concepts:

1. **power electronic converter (PEC)** – *electronic converter* that converts *energy* in a *power electronic system*
2. **dc/dc converter** – PEC converting *dc* to *dc* of another level
3. **load** – object connected to the **PEC** output
4. **supply** – *power line* feeding the **PEC**
5. **boosting** – production of *load voltage* higher than *supply voltage*
6. **booster** – PEC with **boosting** possibilities
7. **boost converter** – **booster**
8. **switching dc converter** – **dc/dc converter** built on a *switching* principle of operation
9. **buck converter** – **switching dc converter** the output *voltage* of which is less than the input *voltage*
10. **buck-boost converter** – **buck converter** combined with a **boost converter**

Here, the concept terms are given by the blue typeface and an italic font is used for the terms incoming from prior disciplines, such as Electronics and Electrical Engineering. The defined concept terms occupy the left side of each row whereas the definitions are to the right. Table 2.11 represents alphabetically ordered concept terms of this thesaurus.

Table 2.11. Fragment of an initial concept table in Power Electronics

i	Term	T_1	T_2
1	boost converter	booster	
2	booster	PEC	boosting
3	boosting	load	supply
4	buck converter	switching dc converter	
5	buck-boost converter	buck converter	boost converter
6	dc/dc converter	PEC	
7	load	PEC	
8	PEC		
9	supply	PEC	
10	switching dc converter	dc/dc converter	

In the table, the defined concept terms occupy the column *Term* of each line whereas the parent terms are given in the columns T_1 and T_2 . Table 2.12 displays the matrix associated with Table 2.11.

Table 2.12. Fragment of an initial concept matrix in Power Electronics

i	Term	j									
		1	2	3	4	5	6	7	8	9	10
1	boost converter		1								
2	booster			1					1		
3	boosting							1		1	
4	buck converter										1
5	buck-boost converter	1			1						
6	dc/dc converter								1		
7	load								1		
8	PEC										
9	supply								1		
10	switching dc converter						1				

In Table 2.13 a fragment of the ordered concept table is presented.

Table 2.13. Fragment of the correct concept table in Power Electronics

i	Term	T_1	T_2
1	PEC		
2	load	PEC	
3	supply	PEC	
4	boosting	load	supply
5	booster	PEC	boosting
6	boost converter	booster	
7	dc/dc converter	PEC	
8	switching dc converter	dc/dc converter	
9	buck converter	switching dc converter	
10	buck-boost converter	buck converter	boost converter

In Table 2.14 the left-triangular matrix of the ordered thesaurus is given.

Table 2.14. Fragment of the correct matrix in Power Electronics

<i>i</i>	Term	<i>j</i>									
		1	2	3	4	5	6	7	8	9	10
1	PEC										
2	load	1									
3	supply	1									
4	boosting		1	1							
5	booster	1									
6	boost converter					1					
7	dc/dc converter	1									
8	switching dc converter							1			
9	buck converter								1		
10	buck-boost converter						1			1	

2.3.3 Thesaurus as a tool for teaching and learning

To create and fill the ET, the teacher designs the source table. To this aim, different database environments may be used, starting from such a simple tool as Excel. Here, an author develops the thesaurus articles, indicating their terms, parents, and definitions. A short fragment is shown in Table 2.15.

Table 2.15. Fragment of the ET source table

Term	Parent 1	Parent 2	Parent 3	Definition	Kids
pn junction	extrinsic semiconductor			region between the <i>extrinsic semiconductor</i> layers	
base curve	input characteristic	BJT		<i>input characteristic of BJT</i>	
BJT	transistor	control terminal	pn junction	<i>transistor with two pn junctions controlled by a current of the control terminal</i>	
control terminal	pn junction			terminal intended for the current control through the <i>pn junctions</i>	
input characteristic	control terminal			current-voltage dependence at the <i>control terminal</i>	
extrinsic semiconductor				semiconductor with impurities	

Following the preparation of the source table, the ranking procedure must be initialised. The ranking program depends on the framework of the source table. To build this program, the object model developed in Chapter 1 was used. Particularly, for Microsoft Excel and Microsoft Access, the Visual Basic macros are applicable. To process more complex databases, the object-oriented languages are to be used. Such program, designed according to the above proposed algorithm, executes the following functions:

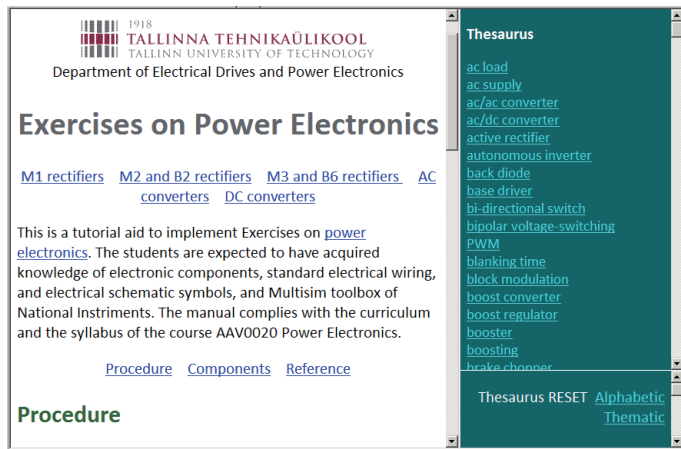
- thesaurus ranking
- error indication and correction
- introducing the new concepts
- concept enumeration
- kids collection and sorting in the column “Kids”
- ET formatting
- ET preparation for printing

In Table 2.16, a fragment of the prepared ET is shown. On the strength of the format universality, the developed database can easily be converted into many databases and Web formats, like dbf, html, xml, etc.

Table 2.16. Fragment of the ranked ET

#	Term	Parent 1	Parent 2	Parent 3	Definition	Kids
1	transistor					BJT
2	extrinsic semiconductor				semiconductor with impurities	pn junction
3	pn junction	extrinsic semiconductor			region between the <i>extrinsic semiconductor</i> layers	BJT, control terminal
4	control terminal	pn junction			terminal intended for the current control through the <i>pn junctions</i>	BJT, input characteristic
5	input characteristic	control terminal			current-voltage dependence at the <i>control terminal</i>	base curve
6	BJT	transistor	control terminal	<i>pn junction</i>	<i>transistor</i> with two <i>pn junctions</i> controlled by a current of the <i>control terminal</i>	base curve
7	base curve	input characteristic	BJT		<i>input characteristic of BJT</i>	

The ranked thesauri accompany many electronic documents of the disciplines related to Electronics instruction in TUT. Using interactive hyperlinks, the ET clarifies and explains the sense of concepts through other learning materials, such as lectures and practical guidelines. This hierarchically structured interactive dictionary interprets now about 1000 concepts in Electronics and Power Electronics. Each of its articles has a semantic (meaningful) relationship with the definitions given preliminarily.



a.



b.

Figure 2.6. Fragments of the tutorial aids accompanied by the ET

To build the user interface of the thesaurus, both the database structure and the Concept Map toolbox were applied [Z23], [Z30].

In the database table, an alphabetically ordered index of the thesaurus is arranged. Another choice is a thematic index used to guide the learner throughout the course, from the root concept to the leaves of the knowledge tree. In Figure 2.6, a, the screen dump of a Web tutorial aid is shown which covers the exercises in Power Electronics with the thesaurus entry in the database form. Figure 2.6, b represents a fragment related to the lab tutorial in Electronics. The frame of the thesaurus includes the following areas:

- concept name
- definition area in which the parents are presented in the form of hyperlinks with the appropriate thesaurus entries
- the kid area where the inheritable concepts are listed, arranged in the form of hyperlinks with the appropriate thesaurus entries

As an alternative or additionally to the database topology, the concept map [0705] [0805], [0819] can be used as the ET graphical organising tool. Particularly, the concept map of the Power Electronics thesaurus comprises six files interconnected by the hyperlinks – “Introduction”, “Rectifiers”, “Inverters”, “AC/AC Converters”, “DC/DC Converters”, and “Utility Circuits”. The Electronics concept map arrangement comprises four files interconnected by the hyperlinks – “Semiconductor Devices”, “Electronic Components”, “Analogue Electronics”, and “Pulse and Digital Electronics”.

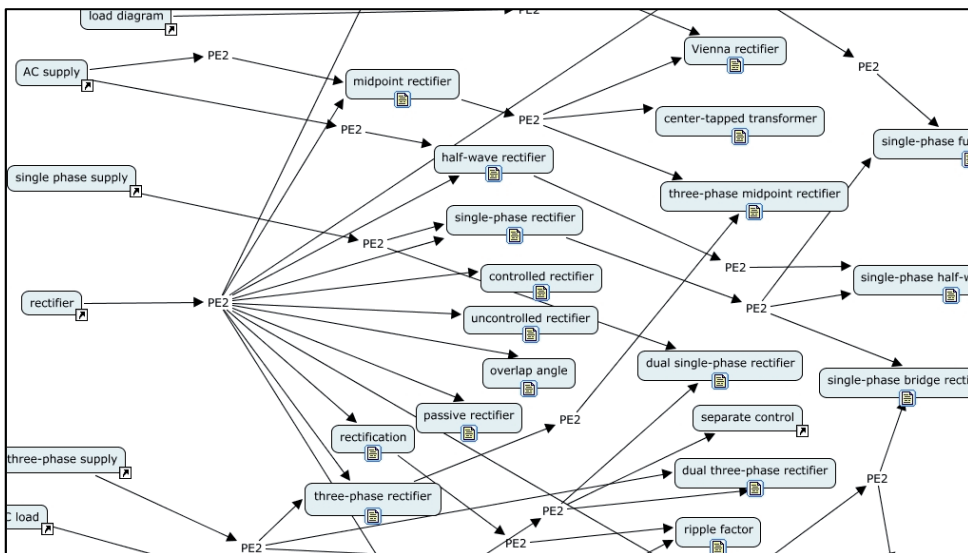


Figure 2.7. Fragment of the ET in Power Electronics shown as a concept map

A fragment of the thesaurus built for Power Electronics is shown in Figure 2.7. It shows the concepts, usually enclosed in circles or boxes of some type, and relationships between the concepts indicated by the connecting lines coupling the concepts. Words on the line referred to as linking words or linking phrases specify

the relationship between the linked concepts. The concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top or left side of the map and the more specific, less general concepts arranged hierarchically below or to the right. The hierarchical structure for a particular domain of knowledge also depends on the context in which that knowledge is being applied or considered.

2.3.4 Resume

1. To test the developed approach to assembling the thesaurus, a case study from Electronics was conducted in which all the ET models were converted and ranked in the best order.

2. Next, a similar application example from Power Electronics was explored and ranked.

3. To prepare the ET, the teacher designs the source table using different database environments starting from such a simple tool as Excel, which can easily be converted into many databases and Web formats, like dbf, html, xml, etc.

4. The last section explains how the developed thesauri accompany the tutorial aids of the disciplines related to interpreting more than 1000 concepts of electronics by means of the database and the concept map user interfaces.

2.4 Summary of Chapter 2

An analysis conducted revealed the drawbacks of the conventional thesauri from the educational viewpoint and became the starting point for the development of the new tool, namely an educational thesaurus. To meet learners' expectations, the principles of the ET design were proposed in this chapter. Following these principles, effective filling and ranking procedures and algorithms were developed that prevent conceptual recursion and repetition, restrict the number of parents in the new concept definitions, and promote concept redefining.

Cited examples and implementation results confirm suitability of the thesaurus for learning management. As opposed to the traditional environment, the system allows finding the starting position at which concepts may be introduced into the ET.

The chapter highlights the main benefits of using the ET in which both the student and the teacher can follow up the meaning of each concept. Application of the thesaurus is important for the conceptual thinking and appreciation of the learning process because a student may learn the discipline in a logical manner, thus creating his/her own professional field of knowledge. The online thesauri enable the learners to overcome the barrier between the practical application and the theoretical knowledge. They promote learning and ultimately students' progress and achievement and have major influence on what learners learn, how effectively they learn, and consequently on the quality of their learning.

CHAPTER 3. ARRANGEMENT OF ACTIVE LEARNING FOR BACHELOR'S STUDY OF ELECTRONICS AND POWER ELECTRONICS

3.1 Development of Active Learning Technology

3.1.1 Academic performance in the scope of active learning

An active learning technology was chosen at the Department of Electrical Drives and Power Electronics of TUT as a prospective educational instrument. It was first developed by the author for the course Power Electronics (AAV0020) [Z04], [Z12]. Next, the disciplines Electronics (AAR3320) and Advanced Course of Power Electronics (AAV0050) were involved [Z17], [Z20] to the research.

The research was conducted during 2009, 2010, 2011, and 2012. Annually, the students of two specialities are enrolled on three subjects, as shown in Figure 3.1. Two groups of 50 students study Electronics offered within the bachelor's Power Engineering curriculum. One bachelor's student group of approximately 25 studies Electronics and Power Electronics in the specialisation of Electrical Drives and Power Electronics, and one master's group learns Advanced Course of Power Electronics. Totally, above 300 students participated in the case study.

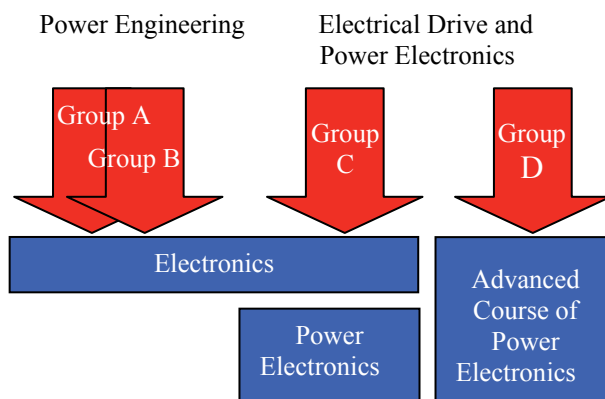


Figure 3.1. Speciality-group-discipline diagram

The course syllabi include lectures, laboratory works, exercises, homework, and assessment. The program follows quite a regular structure of engineering classes, such as two hours of lecturing and one hour of weekly exercises and laboratory work, plus the final exam at the end of the semester [WL27]. The total hours allotted to the particular courses are fixed by the curricula, therefore to introduce alternative learning the prescribed borders between lectures and other kinds of study could not be shifted to allow students spend their learning time in an appropriate way.

The bachelor's courses are compulsory whereas the master's course is optional. As all the disciplines were taught by the same department and teaching staff, a complete and comprehensive curriculum with non-overlapping contents has been provided. Besides, there are some other courses very closely related to these disciplines. As the essential background of circuit analysis is provided by the first-year Electrical Engineering course, students are familiar with linear circuit analysis, including basic passive components, resistors, inductors, and capacitors. In turn, the second year Electronics course gives the required knowledge about the basic electronic components needed for the third-year Power Electronics and Electrical Drives courses and for Advanced Course of Power Electronics at the master's level. Electronics aims at learning fundamentals of components, including semiconductor principles and basic analogue and digital circuits with electronic parts, as well as basic laboratory procedures and circuit calculation and simulation in exercises. Power Electronics focuses on electronic converters for different industrial and domestic applications. The following Advanced Course of Power Electronics relates to electromechanical applications of electrical machines fed by electronic converters.

In this environment, the objectives of the new course arrangement were to enlarge the learning opportunities for different groups of students, both the strong and the weak ones, in accordance with their targets and real possibilities [1005], [1006].

To achieve the goals of active learning, a novel format of the courses has been prepared that differs from traditional teaching. Exposing engineering students to a real working environment provides them with a complimentary and fundamental view about engineering, being a key component in the Bologna process [WL08]. Exercises and lab tasks being the part of the syllabus play the primary role in this format. In the scope of the described educational environment, the theoretical studies are not always run before taking the practical classes. To part of students, it is better to pass the theoretical studies first, but other students prefer passing practices first because this can provide a good basis for the theory – this helps students to understand some of the theoretical concepts. Therefore, the training methodology was turned in a way that deploys the contents upon the two layers (Figure 3.2):

- compulsory material as a minimum skill base of the course study (approximately 20–40 % of the study volume)
- optional issues of theoretical, practical, computing, simulation, and assessment areas (the remaining 60–80% of the course)

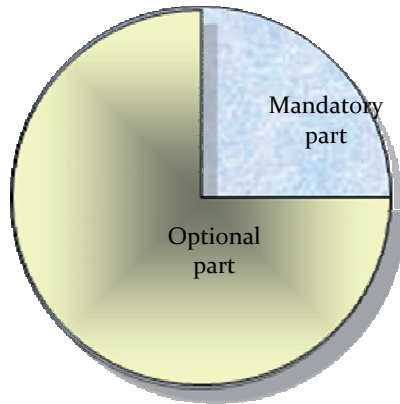
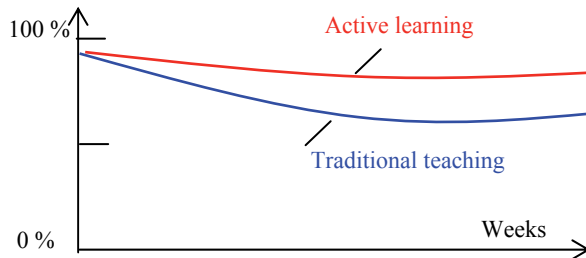
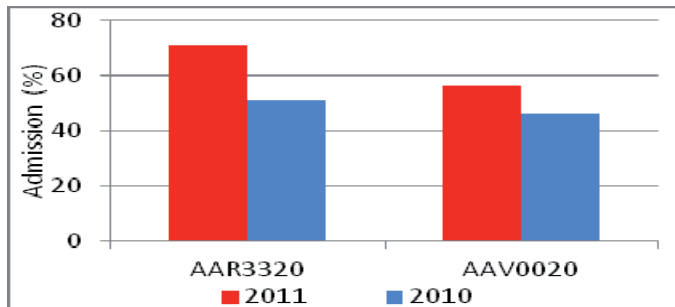


Figure 3.2. Deployment of the course content

The students were requested to participate in active learning voluntarily. With a total number of 300 annually enrolled students, over 90 % responded to active learning technology. According to Figure 3.3, a, those students became encouraged to play an active role in their learning process and to work continuously throughout the course. As Figure 3.3 b shows, an enlarged learner favour to the disciplines was confirmed by the lecture attendance.



a.



b.

Figure 3.3. Trends (a) and dynamics (b) of lecture attendance

Regular work has opened up much greater options of interaction and exchange than the traditional teaching. Some of these are course-relevant and specific, but many active learning tools increased the students' activity. As follows from Figure 3.4, students with intensive participation tended to perform well in the overall course duration and they had higher examination grades than other learners.

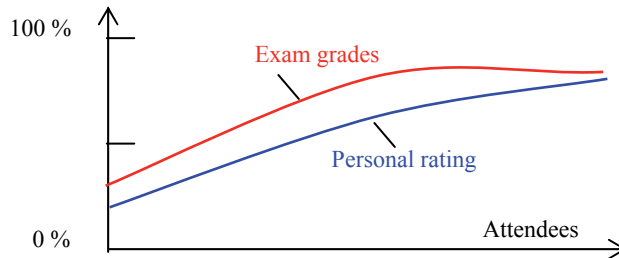


Figure 3.4. Trends of correlation between the students' rating and examination grades

Active learning has resulted in the following positive outcomes:

- active and reciprocal interaction appeared among the students as well as between the learners and lecturers
- the course contents were focused on essentials with an emphasis on the comprehension of the major principles in the fields
- as the students were engaged to employ the new concepts, their conceptual understanding was valued
- learners were stimulated to acquire relevant knowledge from the preceding courses
- teaching the new content became interconnected with the students' prior knowledge

Thus, active learning provides opportunities for talented students to acquire in-depth education, if necessary, engage them in research, and motivate to start an academic career.

In the following sections, a detailed explanation of the developed active learning technology is proposed.

3.1.2 Enhanced methodology of theoretical training

As a first step, the methodology of theoretical training has been improved in a way that deploys the course contents upon the two layers: mandatory and optional. Each lecture consists now of the following four parts:

- pre-lecture discussion of the previous material
- pre-lecture or post-lecture quiz
- teaching the new topic of the mandatory material that may involve in-lecture discussion of correct/incorrect quiz responses
- post-lecture summing-up review

In this way, the courses involved in active learning contain both traditional lectures and self-directed educational material. To provide the learners' appreciation of academic performance, to give them confidence with the material, and to encourage students in learning activation, the main part of theoretical lessons were devoted now to the explanation of the mandatory part of the course. Often, the behaviour analysis replaces the formal explanation. Additionally, the lecturer reviews the marketable designs and products and advises the students about the possible errors or mistakes.

Such methodology helps to develop the following student skills [0815], [0816], [0914]:

- problem statement and deeper knowledge
- understanding learning objectives and the methodology used
- enhanced student collaboration and group working potential

At the same time, not all the students benefit from active learning. Our observations and trends of lecture attendance show that in the first lessons almost all the learners start their work actively. Nevertheless, only part of them participated successfully until the term end. The reason seems to be in the requirements to work regularly throughout the course and to play an active role in the knowledge acquisition process. To obtain high rating, the students need to use additional resources and to devote additional time to their learning. Active learning places obstacles in copying and cheating, engaging self-thinking, quick-wittedness and self-discipline.

In addition, active learning makes heightened demands of teachers. Their operation time rises and requirements to their knowledge level and creativeness increase also. That is why the new approach has both supporters and opponents among the academic staff.

3.1.3 Resources of active learning

Due to the pre-lecture and summing-up discussions and quizzing, the intrinsic lecture time fines off, thus the additional educational resources were recommended to students. The diagram presented the body of active learning resources is given in Figure 3.5.

All resources are divided between the printed materials and the virtual ones. The printed group envelops textbooks, tutorial aids, and manuals for lectures, laboratory work, exercises, tests, and examinations. In the virtual group the web-textbooks, software, e-manuals and databases are represented. In addition to the traditional internal institutional resources, the educational tools of the partners' universities and enterprises are involved as well as the worldwide open Internet resources become accessible for deep learning. Among them, the following software is presented:

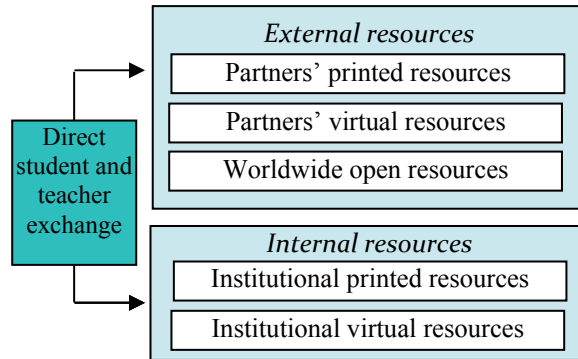


Figure 3.5. Resources of active learning

- Virtual Lab of Riga Technical University, Latvia
- eDrive of TUT, Estonia
- CmapTool of Institute for Human and Machine Cognition, USA
- Weblectures of Delft University of Technology, Netherlands

The students' and teachers' exchange in the frame of the partner agreements and international programmes engages student activity as well. The main partners for such exchange are as follows:

- Kempten and Giessen-Friedberg Universities of Applied Sciences, Germany
- Riga Technical University, Latvia
- Lappeenranta and The Aalto University School of Science and Technology, Finland
- Vilnius Gediminas and Kaunas Technical Universities, Lithuania

It is a remarkable feature of the described approach that a significant volume of the proposed resources is optional. It serves to stimulate the strong students in their success in active learning. At the same time, the weak students acquire mainly the mandatory information presented in the textbooks and manuals.

Thanks to these resources, an active approach became beneficial, leading to deep understanding and development of a conceptual knowledge base. It motivates introduction of international syllabi, proceeds joint curricula design in collaboration with foreign universities, ensures preparedness for instruction in English, attracts international students in the bachelor's and master's programmes, provides broader opportunities for students to take up studies at other recognised universities, and fosters flexible training techniques.

3.1.4 Resume

1. As the traditional teaching has many drawbacks, to enhance student possibilities in knowledge acquisition an active learning technology was introduced

at TUT into the courses of Electronics, Power Electronics, and Advanced Course of Power Electronics.

2. To achieve the goals of active learning, a novel format of the courses has been prepared in which exercises and lab tasks play the primary role and the training methodology was turned in a way that deploys the contents upon the two layers, namely compulsory material and optional issues.

3. Though the students were requested to participate in active learning voluntarily, over 90 % responded to the new approach and became encouraged to play an active role in their learning process and to work continuously throughout the course.

4. A remarkable feature of the proposed approach is the significant volume of the optional resources that engage students in their learning, and have many benefits in the knowledge and skill acquisition.

3.2 Arrangement of Exercises in Electronics and Power Electronics

3.2.1 Modelling and simulation throughout active learning

Modelling and simulation help learners to understand the nature and a performance of the system they study. The act of simulating generally entails representing certain key characteristics or behaviours of a system, device or process under the question. An effective library of models serves as a suitable tool in learning and training. The models help to examine and to predict various situations occurring in a studying system. Moreover, the models may be useful to plan the processes and to carry out different performance steps in laboratories. Future specialists may better answer their questions using computer models [9201].

Over the last decades, simulation of electronic circuits became a major research topic. There has been much progress, but educational acceptance, particularly in cost sensitive areas, has not been high. Although the novel simulation systems were developed to overcome these limitations, they are generally restricted to modelling only those circuits that concern the particular application area [0613].

This section displays the techniques that provide simulation benefits not only for narrow applications, but for the broad education sphere. Upon the active learning approach, the students are responsible themselves for the circuit design and diagnosis. Doing these, they learn to become experts in the circuits and obtain a variety of experiences with most types of circuits. The learners identify the circuit functions and determine how they are supposed to perform. They need then to find the input stimuli and to collect the output data to compare them with the expected response defined in the textbooks and manuals. Beside the system design, students are responsible for defining the diagnostic strategy. This requires them to analyse the circuit and its functional specification. They must determine what faults and

malfunctions were detected and at which tests and inputs the fault propagates [9803].

There are no essential conditions that would be appropriate to every electronic circuit or even to most circuits. The set of requirements that can arise is very diverse due to wide ranges of applications. Also, the relative weighting of importance of various features should vary between particular applications. As electronic circuits are used differently in the fields, the features of high steady-state or dynamic precision, wide frequency and fast time responses, high surge withstand capability, and electrical parameters required by a consumer are often themselves the decisive properties. The frequency range is the usual professional feature for any kind of the electronic circuits. Power regulation is another specialised feature. Efficiency is the significant factor of a converter quality also. Therefore, the list of the circuit properties is extremely rich and their simulation meets numerous problems in the contemporary learning technologies.

Multisim has been selected as the basic simulation tool for the bachelor's learning purpose. Its main modules anticipate the types of circuits [0604]. Each of the components – an R-, L-, C-element, diode, transistor, thyristor, etc. – is inserted into the object and then the behaviours of the overall system are monitored by simulation that produces a description of how the overall system performs. Modelling in Multisim enables clear analysis of all electronic circuits, simple parameter variation in a broad range, and fine possibilities in result evaluation with virtual measurements. The libraries of Multisim are well suited for electronic needs, providing different complexity levels of passive components, amplifiers, and switches, from ideal to precision dynamic models. Its built-in tools enable data processing, frequency analysis, and what is really important, interfacing with other simulation instruments, such as Spice, Simulink, and LabView.

The scope of the described experimental and computation works of the proposed learning system seems more holistic, complex, and different than that indicated in the closest existing systems like [0201], [0601], [0605], or [0606]. It takes advantage of covering the whole spectrum of the learning problems in electronics. Moreover, the experiments and calculations listed below are distributed between the applications and unite them by the common idea and the uniform methodological approach.

3.2.2 Exercise lessons organisation

All exercise lessons incorporate five basic activities that promote active learning and give constructive feedback between the students and instructors involved (Figure 3.6) [Z17]:

- off-site preparation
- in-class pre-work talk
- performance in a lesson

- in-class summing-up discussion
- off-site reporting

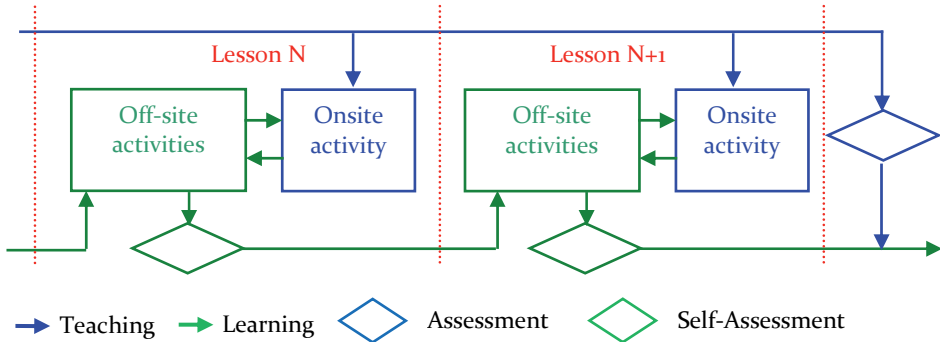


Figure 3.6 Ways for traditional teaching (blue) and active learning (green)

Again, in the mandatory part of those lessons traditional step-by-step instructions are used, resulting in the standard report with the circuit diagrams, calculations, experimental traces, measurement tables, and conclusions. In the new optional part of the exercises, a number of open problems may be framed by the teachers according to the topics in the syllabus. Based on long-term research, such an approach has been accepted, confirming that collaborative learning presents powerful dynamics for knowledge building and supports education at individual, group, and institutional levels [1009].

To enhance appreciation by linking theory and practice, emphasis is on generating student's interest in the engineering methods and tools. As a rule, analytical problems are explained and collaboratively solved along with the mandatory part of the lessons before the personal problem statement. Every block of the lesson starts from the pre-lesson discussion combined with illustrations of application, such as observations and meaningful data as well as their general principles. Herein, the instructor encourages an active participation and facilitates understanding. Herein, students are instructed in technical report preparation, student-to-student, and student-to-teacher collaboration as well as acquainted with the learning resources. This information is available also on the course Internet pages, where all other relevant materials are gradually posted along with the course progress.

In addition to regular classes, self-directed learning issues were included into the exercise practice. To provide effective skill acquisition and to focus teaching and assessment on the needs and abilities of the learners, the existing exercise tasks were redesigned in the scope of the Electronics and Power Electronics courses, as given in Table 3.1.

Table 3.1. Changes in exercise arrangement

Indicator	Traditional teaching	Active learning
Electronics		
Number of lessons	5	7
– including the mandatory ones	5	5
– including the optional ones	0	2
Number of problems	5	32
– including the mandatory ones	5	5
– including the optional ones	0	27
– including circuits for students' self-calculation	0	27
Assessment scores	1	1 to 5
Power Electronics		
Number of lessons	5	5
– including the mandatory ones	5	5
– including the optional ones	0	0
Number of problems	5	27
– including the mandatory ones	5	5
– including the optional ones	0	22
– including circuits for students' self-calculation	0	22
Assessment scores	1	1 to 5

The full range of the exercises accessible by the students has been grouped into the thematic blocks shown in Table 3.2.

Table 3.2. Exercises in Electronics and Power Electronics

#	Code	Thematic block
Electronics		
1	L	Linear circuits
2	F	Filters
3	D	Diode circuits
4	T	Transistor circuits
5	A	Op amps
6	M	Math converters
7	O	Oscillators
Power Electronics		
1	ACDC1	M1 rectifiers
2	ACDC2	M2 and B2 rectifiers
3	ACDC3	M3 and B6 rectifiers
4	AC	M1 and B2 AC converters
5	DC	M1 and B2 DC converters

Each block includes mandatory and optional works; therefore, every student must perform a minimum of five works in a discipline.

The self-prepared flash video “Getting Started Multisim” serves as an instrument to learn about using the Multisim toolkit in the study (Figure 3.7). The video teaches the students how to develop, produce, and simulate power circuits, to detect and remove errors, and to prepare standard reports, thus providing training before the real design of electronic circuits. Here, the students learn to make schematic models in Multisim, select appropriate components, and combine them in the proper order. Later, the students launch the real simulation to understand electrical processes in electronic converters.

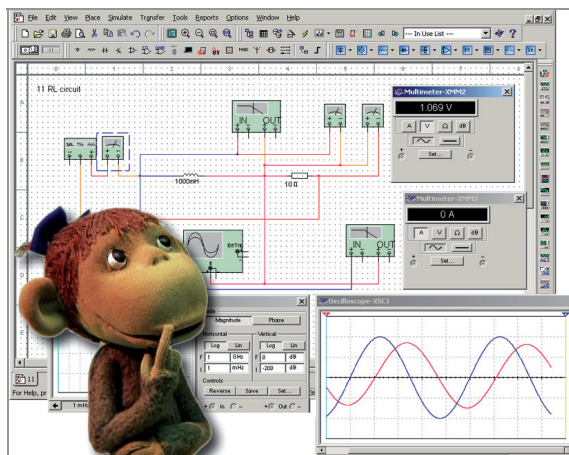


Figure 3.7. A frame of video about using Multisim in Electronics and Power Electronics

To provide successful home preparation for the classes, additional educational resources are recommended to the students in accordance with [WL19]. As a significant volume of the recommended resources is optional, they stimulate strong students' efforts in their success in active learning. At the same time, weak students acquire mainly the mandatory information presented in the textbooks and manuals [0611], [0612].

3.2.3 Exercise implementation

Through the set of exercises discussed, the students practice the following:

- circuits development, commissioning, and improving
- inspection of the proper selection of electronic components
- examining the schematic correctness
- measurement of powers, voltages and currents as well as the frequency response and waveform analysis
- result explanation, reporting, and documentation

The proposed simulation instruments are suitable to compare the calculated and experimental data and to generate a report which typically includes

- experimental diagrams
- resulting and comparative data tables
- voltage and current traces
- dependency diagrams, if required
- conclusions with the explanation of the results obtained

The simulation components and instruments used in computer experiments involve the following models to provide effective design:

- power sources of different principles of operation, such as dc, ac, voltage-controlled, current-controlled, pulse, and clocking
- passive components: resistors and potentiometers, capacitors, inductors and variable inductors, switches and voltage-controlled switches
- diode circuits built on rectifier and Zener diodes, the full-wave bridge rectifiers and the silicon-controlled rectifiers
- transistors, particularly BJTs, FETs, and MOSFETs
- integral circuits, such as opamps, comparators, combinatory and sequential logic
- virtual measuring devices, including multimeters, wattmeters, voltmeters, and ammeters
- special instruments, such as virtual oscilloscopes, function generators, and Bode plotters

At the beginning of a lesson, students must show the teacher the preliminary knowledge by answering a series of theoretical issues related to the practice implemented in the current session. To ensure a maximum profit from exercises it is essential that students undertake this assignment. The teacher highlights in situ the errors that students have done and they correct them herein.

After the implementation of each exercise, students should complete a simplified report consisting of a summary of the major activities performed in each session and containing several basic questions related to the preliminary study and the work activities. In addition, the students add their reflections and questions being raised during the exercises. Off-site the students may develop the optional part of the work and prepare the final report. The next session is mainly intended for students' defence of their results using computer models and computations. Then, the teacher introduces the report corrected, whereas students can analyse their progress and mistakes made.

The evaluation currently applied consists in a continuous assessment throughout the course. The teacher-to-student feedback introduced by the formative assessment permits the imbalances that may occur during the course to be corrected and adaptation of teaching classes to each situation. For this reason, students and teachers have regular information during the course about the teaching/learning

process. As exercises involve both the compulsory and the optional items, a learner may obtain additional scores if he/she implements the optional items. The scoring principle assumes obtaining one score for each solved problem.

3.2.4 Contents of exercises in Electronics

Electronic circuits involve different linear and non-linear electronic components [ZL01], [Z06]. The basic RL, RC, and RLC schematics include resistors, inductors, and capacitors. Their supply is built using the virtual function generators where the sine or meander waveforms of the required frequency may be set. In this way, the series and parallel resonant circuits are explored as well. To view and measure the voltages and currents, multimeters and oscilloscopes are applied, and to obtain the frequency responses the Bode plotter is linked. These virtual devices help to measure circuit currents, component voltage drops, and phase shifts between the current and voltage traces. To provide analysis, calculation of the circuit currents, their phase, and voltage drops on the components and the comparison of the calculated results with the measured ones are provided.

To build the filters, sample schematics have been developed, such as the low-pass, high-pass, band-pass and band-stop filters built on resistors and capacitors or inductors and capacitors. During the analysis procedures, the circuits are supplied from a group of ac voltage sources of different frequencies: low, high, or middle. A virtual oscilloscope and a Bode plotter will analyse the timing diagrams and the frequency responses, measure the output magnitudes and phases whereas the multimeters will count the input and output voltages. The toolbox supports the calculation of the capacities and inductances that provide the cutoff frequency higher or lower than the reference frequency.

A number of diode circuits may be explored in the exercises. To model these circuits, function generators, diodes, and resistors are used. By setting the sinusoidal and triangle waveforms and assigning the reference frequency, different voltage, and current measurements may be provided. Changing the amplitude allows the particular points of the circuit output characteristics to be studied following the plotting of the output diagrams of the forward and reverse biased devices and the knee voltage determining. Among the devices, the common rectifier circuits, series and parallel clippers, diode limiters, and Zener circuits are the most popular examples. The students calculate the required voltage source values to obtain the required clipping voltage levels on the load caused by the sine and triangle signals.

The signal amplifiers built on the transistors may be explored using virtual oscilloscopes, potentiometers, and the traditional measuring devices. To measure the transistor gains, the collector curves with the different base currents, from zero to the maximum signal may be built. To measure the beta and alpha gains, the input characteristics are built. Students find the dc supply voltage that provides the reference unclipped output signal with inverse sine waveforms. If necessary, the base bias and input voltage are changed during the simulation. The circuit voltage gain should be found as well. By analogy, in the common base amplifiers the

maximum amplitude of the function generator, which provides the unclipped sine output near the reference voltage and the circuit voltage gain, may be found. The emitter followers are effectively discovered in the same way.

To develop the non-inverting voltage amplifiers, they are connected to the virtual function generators supplied with the sine waveform signals of the reference frequency. Students calculate and assign the required feedback resistances and the generator amplitudes that provide the reference unclipped output. Using the function generator to view the input and output voltages and a Bode plotter to view the frequency response, the signal voltages, their magnitude and bandwidth are evaluated and the voltage gain calculated. Also, the students plot the diagrams of the bandwidth versus the voltage gain. In the same way, it is suitable to calculate and assign the required feedback resistance and the function generator amplitude that provides the required unclipped output of the inverting voltage amplifiers. The same concerns the voltage gain and the bandwidth calculation along with plotting the diagrams of the system bandwidth versus the voltage gain.

Some methods to study detectors of different types built on comparators were developed. It concerns the null-point detector with the balanced supply, the positive reference detector, and the negative reference detector. To find and measure their hysteresis, it is suitable to the oscilloscope traces. Input and output characteristics of the detectors keep data about their modes of operation. In the Schmitt triggers, the hysteresis width may be measured and adjusted. By the way, the diagram of the hysteresis width versus the positive voltage gain is plotted.

Different kinds of math converters may be designed, explored, and tuned using the system described. Particularly for the dual-input summers built on op amps, students calculate and assign the dc voltage source signals that provide the necessary unclipped output. By changing the ac and dc voltages, a user may view and measure the sum of the input voltages to compare the output voltage with the calculated one. By analogy, the dual-input subtractors, integrators, differentiators, and PID-regulators may be explored using the virtual opamps, function generators, dc voltage sources, capacitors, and resistors. Students find their source voltages that provide the reference unclipped or rectangle output and compare the output voltages with the calculated ones.

Among the oscillators, such kinds of models are developed as the symmetrical and asymmetrical astable multivibrators and the Wien bridge oscillators with unipolar and balanced supply. Students count and assign the capacitances and the dc voltage values that provide the required frequencies and outputs, demonstrate the input and output voltages, and compare the calculated results with experimental ones.

3.2.5 Contents of exercises in Power Electronics

An original simulation technique has been developed to support learning the main types of power converters [ZL01], [Z07].

First, it concerns the single-phase half-wave rectifiers, particularly the simple M1 diode and thyristor rectifiers that drive the resistive and inductive loads. Using a virtual current-controlled voltage source and an oscilloscope, this technique helps to explore the load voltages and currents, to calculate the required supply and peak inverse voltages of the diodes, to measure the average voltages and currents, and to view the diode inverse voltage. It is suitable to measure the peak-to-peak ripple voltage and to calculate the ripple factor of the output waveform and the power factor of the circuits. By experimentation, recommendations may be given how to decrease the ripple factor and to filter the signal. For the thyristor rectifiers, the methods were proposed how to calculate the required supply voltage, to reduce or enlarge the firing angle, to measure the load voltage, and to build the control curve.

Similarly, the schematic to study the single-phase full-wave rectifiers is proposed using the virtual mid-point transformer, function generator, diodes, measurement devices, and the load. The learning system provides the calculation of the required average load voltage and current as well as the supply voltage of each half-winding. It helps to measure the load voltage and current and to examine both voltage and current. For the M2 rectifiers, students calculate the peak inverse voltage on each diode and evaluate the peak-to-peak ripple voltage as well as the ripple factor for the output waveform. The measures are suggested how to decrease the ripple factor and to build a filter supported by the calculation of the filter parameters and the actual ripple factor.

To study the M2 thyristor rectifiers, students design simple gate drivers using a virtual pulse voltage source. After activating the circuit, the signals are displayed and measured. The student obtains the possibility to view, explain, and document the results, to change the load, and to build the load curve that is the diagram of the load voltage versus the load current. It is possible to study the active and inductive loading process of the rectifier. The same algorithm is proposed for the simple B2 bridge rectifiers and for their filters. To compensate the phase shift of the inductive load, a low-pass filter may be calculated or found experimentally, which decreases the ripple factor. Regarding the B2 thyristor rectifiers, an analysis of the load current, measuring the average voltages and currents, as well as the calculation of the required average load voltage, load current, and supply voltage are provided. To simulate the gate driver, the pulse voltage source is used as a firing regulator. Change in its delay time results in the output voltage adjusting.

Learning the three-phase rectifiers begins usually from building a schematic use of the ac voltage source, diodes, and a load. A virtual oscilloscope demonstrates the load voltage. To view the load current, the current-controlled voltage source is connected in series with the load. To measure the dc voltage and current, a dc voltmeter across the load and a dc ammeter in series with the load are used. Students

calculate the required average load voltage, load current, and supply voltage and assign the necessary phase shifts of each voltage source – 0 degrees, 240 degrees, and 120 degrees, respectively. Similar tools are used to evaluate M3 thyristor rectifiers and B6 diode and thyristor rectifiers. Again, the system provides plotting the schematic, examining the load voltage and current, measuring the average voltages and currents, as well as calculating the average values for the load voltage, the load current and the required supply voltages.

In ac converters, the influence of the switching parameters on the system action is strong enough. For this reason, the application of ideal switches instead of the switching thyristors and transistors is recommended as the first step of the converter discovering. Then, the ideal switches are replaced by the virtual semiconductor switches to continue the power system exploration.

Particularly, to find the characteristics of the single-phase voltage regulators the voltage-controlled switches supplied by the pulse voltage sources are used on the first stage. After the circuit assembling, the period and the pulse width are assigned in the pulse voltage sources that supply the ideal switches. To view the load current, the current-controlled voltage sources connected in series with the load play the role of the current sensors that drive an oscilloscope. To measure the load voltage and current, an ac voltmeter across the load and an ac ammeter in series with the load are mounted. The pulse voltage source delay time and pulse width may be used as the switching regulation options. Simultaneous changing of these parameters results in the diagram tracing where the load voltage and delay are interconnected. Following exploring the ideal system, the voltage-controlled switch may be replaced with a pair of back-to-back connected thyristors. The personal gate driver of each thyristor is modelled by the pulse voltage sources between the gate and the cathode. From now on, the signals may be analysed and the load voltage and current measured. Again, it is suitable to build the diagram of the load voltage versus the firing angle as well as the load curves (load voltage versus current) of the thyristor system.

Consequently, learning the single-phase bridge inverters begins from the schematic development based on the dc voltage source and voltage-controlled switches, the pulse voltage source, and the load. An oscilloscope displays the load voltage and the load current. To measure the voltage and current, an ac voltmeter across the load and an ac ammeter in series with the load are mounted. To build a gate driver, a couple of pulse voltage sources are connected. In each pulse voltage source, the period, pulse width, and delay time are adjusted to control the converter. Particularly, to change the load frequency, simultaneous varying of period option of both pulse voltage sources and delay time of the second pulse voltage source are needed. To adjust the load voltage, simultaneous varying of the pulse width option of both pulse voltage sources is required. To evaluate the converter operation, the diagram of the load voltage versus the duty cycle is processed. Follow the ideal system exploring the voltage-controlled switches are replaced with MOSFETs. From now on, the signals may be analysed and the load voltage and current

measured. Again, it is suitable to build the diagram of the load voltage versus the duty cycle as well as the load curves of the MOSFET system.

To investigate the voltage source and current source inverters, the ideal switches of the same schematic as in the previous case may be used. To build a new gate driver, the function generator and comparators may serve as the basic components where signal recognising and the load voltage and current measuring are provided. To change the load frequency, the function generator frequency is tuned whereas to change the load voltage, the function generator duty cycle option is varied. Here, the diagram of the load voltage versus the duty cycle may be presented. Following the ideal system exploring, the voltage-controlled switches are replaced with MOSFETs. From now on, the signals may be analysed and the load voltage and current measured. Again, it is suitable to build the diagram of the load voltage versus the duty cycle as well as the load curves of the MOSFET system. To build a current source inverter, the dc voltage source is replaced with a dc current source. To build the diagram of the load current versus the duty cycle, the load current is adjusted by changing the function generator duty cycle.

The same concerns the frequency converters. Their exploring involves recognising the signals and measuring the load voltage and current. To change the load frequency, the function generator is adjusted whereas to change the load voltage, the source voltage is varied in turn. Then, replacement of the voltage-controlled switches with the three-terminal enhancement n-MOSFETs is required. The signals may be inspected and the load voltage and current are measured. By changing the load resistance, the load curve of the MOSFET system is generated. Additionally, parameters of an inductive filter in series with the load may be found to improve the output data.

The four most convenient types of dc/dc converters are studied by the toolbox described – the buck converters, the boost converters, the buck-boost converters, and the Cuk choppers. All the simulation modes support the ideal switches and the real MOSFETs simulation. The system serves to calculate the required load voltage and load current, to view the load voltage and current, to measure the load voltage and current, to build the gate drivers, to find the filter properties for the ripple lowering, to find the gate driver duty cycle as a switching regulator, to reduce and to step up the load voltage, and to build the diagram of the load voltage versus the duty cycle.

Following the replacement of the voltage-controlled switches with the three-terminal enhancement n-MOSFETs, the tracing of the load curve for the MOSFET system is provided additionally. To stabilise the load voltage in the closed-loop buck and boost converters, the gate driver is reconstructed and the negative close loop is arranged. In turn, in the step-down and step-up converters and in the Cuk choppers it is suitable to arrange an external filter which decreases the ripple factor.

3.2.6 Resume

1. This section displays the techniques that provide simulation benefits at the active learning approach making the students responsible themselves for the circuit design and diagnosis, teaching to become experts in the circuits, and obtaining a variety of experiences with most types of circuits.

2. The scope of the experimental and computation works of the proposed learning system seems more holistic, complex, and different from that indicated in the closest existing systems, thus taking advantage of covering the whole spectrum of the learning problems in electronics.

3. All exercise lessons incorporate five basic activities that promote active learning and give constructive feedback between the students and instructors involved, namely off-site preparation, in-class pre-work talk, performance in a lesson, in-class summing-up discussion, and off-site reporting, each included mandatory and optional works.

4. The evaluation currently applied consists in a continuous assessment throughout the course, thus students and teachers have regular information during the course about the teaching/learning process and it enables them to focus on the design of effective systems in their activity.

3.3 Arrangement of Labs in Electronics and Power Electronics

3.3.1 Review of traditional laboratory practices

Laboratory works play an important role in the learning process, substantially increasing students' understanding of the studying material. These classes are the necessary part of a curriculum for engineering courses where the practical systems are implemented based on the theoretical lessons. Such kind of activity directs students towards the following learning goals:

- to gain skills and experience with practice
- to gather, manipulate, and interpret data
- to develop cooperation and group work in which students learn to communicate in order to distribute the workload, discuss problems, and integrate the overall program
- to become motivated and excited

Experimentation proposes stages like these:

- circuit development and calculation
- schematic composition
- voltage, current, and power measurements
- analysis of voltage and current traces
- building the static, loading, and control diagrams

- assessment of the prepared schemes and their diagnosis
- drawing conclusions and additional recommendations

Nevertheless, traditional labs suffer from the following disadvantages [0809], [0821]:

- guided practical sessions often promote a passive student attitude who only fills in the notebook and carries out the required task without appreciation the concepts that underlie the work
- “parasitism” is possible under this policy as some students in the group can do all the work, while the others do no work at all
- frequently practical sessions do not investigate a real system but merely work as an example of theoretical concepts, so there is not much additional teaching in these lessons
- current lessons have just a repetitive structure built on the calculation tasks where data are changed from one form to another bearing no relation to the real industrial settings
- traditional practice arrangement promotes neither competitiveness amongst students nor the ability to assign the tasks.

Thus in summary, the traditional labs encourage a surface approach to learning, where students try to follow the routine solution procedures and match patterns rather than engage in a deep approach, where learners develop a conceptual understanding of how the technical system operates. A surface approach focuses on repetition what has been read without necessarily understanding it. Students’ study that is directed almost exclusively on credits will lead eventually to an overload, which in turn tends to result in a low level of knowledge being ineffective in generating student enthusiasm and passion for learning. In this case, students may not fully achieve the required goals and are slow to open their creative talents and engineering potential.

3.3.2 Organisation of active laboratory learning

Unlike the traditional teaching, laboratory works play the primary role in the novel format of the course [Z12]. In the scope of the described educational environment, the labs may flow along with the lectures or they may follow the lectures as well as precede them, if necessary. Being the major step of active learning, the methodology of laboratory training was improved in a way that deploys the practical contents upon the two layers, similar to the exercises:

- mandatory material as a minimum skill base of bachelor’s study in the course (approximately 40% of the study volume)
- optional material, which involves theoretical, practical, computing, simulation, and assessment areas (the rest 60% of the course)

Therefore, besides regular classes, laboratory practice contains self-directed learning issues. Further, a case study in Power Electronics is described.

To provide an effective skill acquisition and to centre teaching and assessment on the needs and abilities of the learners, the existing Power Electronics laboratory tasks were redesigned, as given in Table 3.3.

Table 3.3. Changes in laboratory arrangement

Indicator	Traditional teaching	Active learning
Number of labs	6	10
– including the mandatory ones	6	6
– including the optional ones	0	4
Number of experiments	15	30
– including the mandatory ones	15	10
– including the optional ones	0	20
– including the circuits for the students' own design	11	29
– including the mandatory calculations	16	42
– including the optional calculations	0	86
Number of open problems	23	60
Assessment score	1	1 to 5

The mandatory part of the classes is operated in accordance with the traditional step-by-step instructions resulting in the standard report with the circuit diagrams, calculations, experimental traces, measurement tables, and conclusions. The new optional part of the lessons may be processed using the informal instructions and fresh ideas from both the teachers and learners.

The full range of the laboratory works accessible by the students is shown in Table 3.4.

Table 3.4. Laboratory works in Power Electronics

#	Code	Work title
<i>Block 1 – Diode rectifiers</i>		
1	DM1	Diode rectifier M1
2	DM2	Diode rectifier M2
3	DB2	Diode rectifier B2
4	DM3	Diode rectifier M3
5	DB6	Diode rectifier B6
<i>Block 2 – Thyristor rectifiers</i>		
6	SM1	Thyristor rectifier M1
7	SB2	Thyristor rectifier B2
8	SB6	Thyristor rectifier B6
<i>Block 3 – Transistor dc/dc converters</i>		
9	TM1	Single-quadrant converter M1
10	TB2	Multi-quadrant converter B2

A package of the three learning objects manages the implementation of the laboratory works in Power Electronics. The objects “Diode rectifiers”, “Thyristor rectifiers” and “Transistor dc/dc converters” include a guidance, circuit diagrams, formulae, and questions.

Each block includes the mandatory and the optional works; therefore, every student must perform a minimum of six works, as shown in Table 3.5.

Table 3.5. Works sharing among the teams

Lesson	Works for the teams			
	Team 1	Team 2	Team 3	Team 4
1	SM1	TM1	DM1	DB2
2	SB2	TB2	DB2	DM3
3	TM1	SB2	DM3	DB6
4	DB2	DM2	SM1	TM1
5	DM3	DB2	SB2	TB2
6	DB6	DM3	TB2	SB2

The same concerns the course of Electronics. The package of the four learning objects manages implementation of the laboratory works in Electronics. The objects “Diodes”, “Thyristors”, “Transistors”, and “Operation Amplifiers” include detailed guidance, circuit diagrams, formulae, and questions.

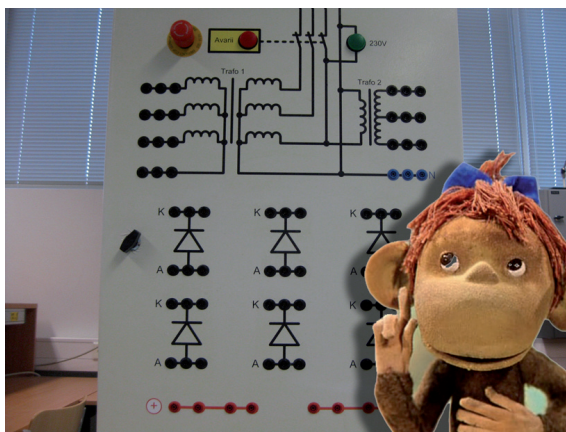


Figure 3.8. A frame of a video about laboratory stands in Power Electronics

To provide successful home preparation for the classes, additional optional educational resources were recommended [0612], [0821], [0824] that usually stimulate strong students’ efforts in their success in active learning. At the same

time, weak students acquire mainly the mandatory information presented in the textbooks and manuals.

The learning flash videos “Getting Started Diode Rectifiers”, “Getting Started Thyristor Rectifiers”, and “Getting Started IGBT Converters” describe the basic components and the related rules of laboratory experimentation in Power Electronics (Figure 3.8). As the stands are complex electronic devices, the videos help to prepare for the laboratory works during the work preparation, before the real tests are performed. Implementing experiments with virtual learning objects provides an opportunity to visualise and explore the complex equipment before the lab start. Preliminary acquaintance with the operational rules gives the students an opportunity to save valuable time for laboratory experiments.

3.3.3 Implementation of laboratory practice

The principles of lab arrangement were developed in the context of active learning. To enhance appreciation by linking theory and practice, emphasis is on generating student interest in the engineering methods and tools. As a rule, analytical problems are explained and collaboratively solved before the experiments. Herein, the instructor encourages an active participation and facilitates understanding. Along with experimentation, students are trained in technical report preparation through iterations to produce quality study reports using the Internet resources.

Every block of practice starts from pre-lesson explanations combined with illustrations of application, such as observations and meaningful data as well as their general principles. Emphasis is on

- description of the block goals, tasks and outcomes
- rules of assessment and criteria of scoring
- recommendation on the student-to-student collaboration
- basic principles of the student-to-teacher collaboration
- description of the final grade and its components
- information about the learning resources

All laboratory works incorporate the same five basic activities as in the exercise lessons, namely:

- off-site preparation
- in-class pre-work talk
- implementation of a laboratory work
- in-class summing-up discussion
- off-site report generation and defence

Each student of a working team has his/her own responsibility in the work. One of them responsible for circuit assembling will develop the circuit diagram and will lead a team during circuit assembling. Since the circuit is prepared without an instructor’s help, he/she obtains his/her personal score. The second team member is responsible for the calculations provided during and after experimentation. Since the

calculation results match the experimental ones, he/she obtains his/her personal score. The third team participant keeps the minutes and plots the diagrams along with the experimentation. Since the diagrams will be ready within the lesson, he/she obtains his/her score also. These roles change weekly, therefore everybody learns to play all the roles.

Every laboratory work involves both the mandatory and the optional items. A team member may obtain additional scores if the team implements the optional items. By answering the questions given at the end of the laboratory blocks, the students obtain additional scores. The average number of problems to be solved in a block on average amounts to 10. Again, solution of only one problem in a lesson is mandatory, whereas the other ones are optional. The number of variants is equal to the number of students. The scoring principle assumes obtaining one score for each solved problem.

In addition to the skills developed in theoretical training, the described practice arrangement helps to develop the following practical skills [0815], [0816], [0914]:

- solution of problems upon the practical headings
- effective calculations, experimentation performance, and equipment selection
- practical experience and qualification acquisition

3.3.4 Resume

1. Traditional laboratory practice provides ineffective techniques for the acquisition of experience and skills due to the surface-based approach to learning and evident learners' orientation to credits without opening their creative talents and engineering potential.

2. In contrast, the active approach to practice includes the mandatory part operated in accordance with the traditional step-by-step instructions and the new optional part based on additional educational resources that stimulate strong students' efforts in their success in active learning.

3. All laboratory works incorporate the same five basic activities as in the exercise lessons, namely off-site preparation, in-class pre-work talk, implementation of a laboratory work, in-class summing-up discussion, and off-site report generation and defence.

4. In addition to the skills developed in theoretical training, the described practice arrangement helps to develop such practical skills as the problem solution upon practical headings, effective calculations, experimentation performance, and equipment selection, and practical experience and qualification acquisition.

3.4 Development of the Self-Assessment System

3.4.1 Assessment in an active learning context

It is a tradition that the grading and assessment schemes are largely prescribed by the host university. This evaluation division between the examinations and the practical credits is usually given in the curricula. The students are required to take the theory exams, as these exams serve to qualify them for the next semester. The inability to assess higher order cognitive understanding and affective attributes via such assessment are often cited [0816], [0913]. Also, in the practice estimation process, the questions posed to students regarding important aspects of their work typically give a subjective and narrow mark. Such traditional “paper and pencil” assessment methods are usually criticised as too much oriented towards the exams, with very few other forms of evaluation and feedback being used [0815]. When the sole purpose of an assessment is to measure the ability of students to respond to the questions asked in the form of credits and examinations, it does not answer whether the students can apply that knowledge and use it in the real world [0914]. Here, the assessment is not considered as a part of the learning process, but rather something that takes place at a fixed time during the academic year.

Meanwhile, an assessment in the context of active learning is required to promote learning and ultimately students’ progress and achievement and has a major influence on what learners learn, how effectively they learn and consequently on the quality of their learning. Undoubtedly, the effectiveness of curricula as well as the overall advancement of engineering education is dependent on how well the instructors understand the role of assessment in learning. If assessment is considered as an integral part of learning, the students will be stimulated to adopt a deep learning approach, which is characterised by making connections and actively searching the meaning and appreciation of the given tasks. This is a prerequisite for the development of critical thinking [0403] where all the participants of active learning employ assessment as a tool for the enhancement of education.

One significant peculiarity of traditional engineering education is the difficulty in the practical application of the theoretical knowledge base. The knowledge transference from the classroom to the new situations and contexts may not occur spontaneously. In most cases, deliberate teaching interventions are needed in order to increase the probability of such a transference occurring [0911].

Therefore, the evaluation strategy was redefined and reformulated for the goals of active learning to stimulate a learner by assessment and to receive currently the actual feedback. At the offered approach, active learning became a way to overpass the barrier between the practical application and the theoretical knowledge [Z20]. Unlike the traditional assessment that tends to focus only on an evaluation of learning and largely fails to consider assessment as a tool of improving learning, an effort has been made to transfer from assessment *of* learning towards a strategy of assessment *for* learning [9901], [0403], [0503]. Assessment in the context of active learning introduced in Electronics, Power Electronics, and Advanced Course of

Power Electronics promotes learning and ultimately students' progress and achievement and has a major influence on what learners learn, how effectively they learn, and consequently on the quality of their learning.

As the main drivers for the student motivation are the formative role of mistakes, the transition was made from the “one-shot process” (Variant A in Figure 3.9) to “continuous evaluation” (Variant B in Figure 3.9). The developed assessment model performs several iterations in the course time span, including learning and evaluation in the common cycle. Here a formative approach is supported by improving learning through a fast feedback and by adapting learning to the student's pace. In our approach, assessment does not take place only at a fixed time during the year. The offered assessment procedure was built into the educational process to monitor the progress of students regularly and to apply it as a guideline of the students' achievements. This approach is used as a way of reflection and feedback for instructors in gauging problem areas, identifying weaknesses, and addressing issues in order to see where students are in terms of their learning progress. Moreover, the new assessment also changed the students' mind in order to make use of assessment as a learning tool, and not just to pass examinations. It favours integration of evaluation, teaching, and learning tasks, which became authentic, meaningful, and engaging. The key features of this approach propose an active participation of learners as the active and informed participants in the assessment of their own performance and in the development of reflective thinking [0821].

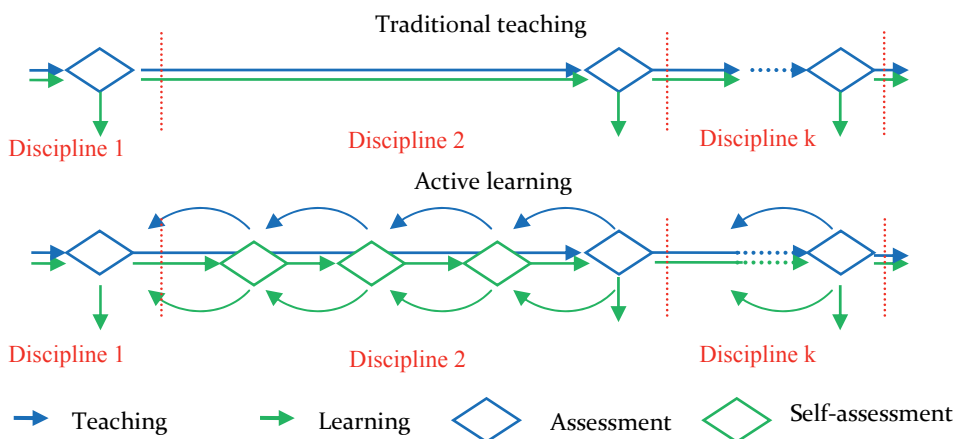


Figure 3.9 Traditional and active assessment variants

3.4.2 Assessment throughout lectures

The bachelor's and master's curricula for Electrical Drives and Power Electronics have solid foundations in physics and mathematics, with the expectation that students connect mathematical and physical concepts to the engineering practice of design and maintenance. However, it appeared that the relationships between theory

and engineering have not been clearly communicated to students through the curriculum, resulting in a high dropout rate and low students retention. Students' perceptions on this issue demonstrated lack of clear communication. Accordingly, one of the main goals of our teaching was to impart students' ability to apply knowledge in different life situations [9602]. Instead of using instructions on a knowledge framework creation, it was argued that an instructor would give guidance and support and thus help learners to become actively involved in the skill acquisition process. Hence, intensive and direct teaching of learning strategies in electrical engineering, including practice and training in the use of those tools, should help the students to succeed in their learning.

Figure 3.10 represents the scheme of assessment throughout the lectures. It includes initial introducing of assessment criteria, regular pre-lecture assignments, on-lecture quizzing, and summary-up discussions.

To stimulate learners' activity, at the beginning of every course the assessment criteria are introduced, which are mutually agreed between the students and lecturer. In the first lesson, all tasks are described and their influence on the final grade is explained and justified. The main components of the final grade are clarified here. This information is available also on the course Internet pages, where all other relevant materials are gradually posted as the discipline progresses.

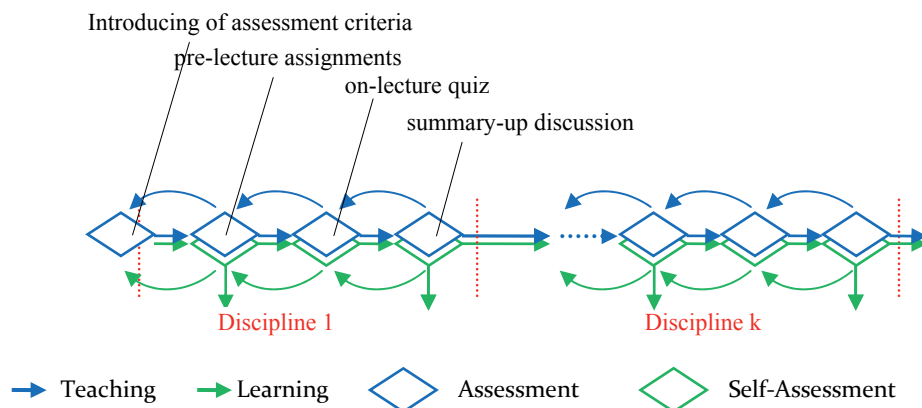


Figure 3.10 Diagram of assessment throughout lectures

To make lectures more appealing for students, the pre-lecture assignments and concept tests are used regularly. The pre-lecture talk and the summing-up discussion that finalises each lecture promote active learning. In addition, they give constructive feedback to the students involved. If some students cannot be active enough, they also obtain feedback in the form of a request to be more active.

At the beginning of most of the lectures, the students take a quiz covering issues from the preceding lectures. During the term, the tutor may give 5 to 10 assignments, each containing 15 to 25 questions. Students are asked to find from

one to four correct answers to all the questions from each question form. The quizzing takes usually 5 to 10 minutes. Immediately afterwards, the lecturer discusses the main test problems. This discussion covers both the correct responses and the typical bugs to the alternatives of the multiple-choice questions taking additional 5 to 10 minutes. Sometimes, at the end of a lecture a summing-up discussion stimulates the students' activity again. Also, it gives constructive feedback from the formal explanation to the active use of knowledge, which teaches the students to trust their formal conclusions and to understand the drawbacks of their answers.

The in-site quizzes with selected-response questions are used regularly as an important tool for learning monitoring. For a lecturer, the results of quizzes become the basis for the next pre-lecture discussion. The student obtains useful information that helps to find the points of weakness in a course, showing, which topics or chapters are to be reviewed to meet the students' needs and to make these parts more understandable. Using such a feedback in the active learning classroom, the instructor adjusts lecture contents based on student responses to warm-up assignments and comes to the lesson with proper knowledge of student questions and concerns. For students, the quizzing results act as assessment scores. Students are more attentive in class because the lecture contents are adjusted to their level of appreciation and students' minds are addressed through properly designed classroom discussions.

As a rule, a question form includes some groups of problems. The main group concerns the issues from the preceding lesson. The second group relates to the past lectures. Historical facts and the names of scientists are the typical questions of all quizzes. Some questions are devoted to the common system theory and the basics of electrical engineering, such as Ohm and Kirchhoff's circuit laws. Calculations based on the mental arithmetic also accompany each quiz. As the discussed courses are given in English, language competence undoubtedly helps to acquire higher scores.

The scoring principle is sufficiently simple: +1 is given for each correct answer and -1 for an incorrect answer. Thus, the penalties for the wrong answers protect from unprepared participation. The subject area of the forthcoming quiz is announced in advance, thus the students may read up for the quiz in time.

Immediately afterwards or at the beginning of the next lecture, the lecturer discusses the test problems. This discussion touches both the correct and the incorrect responses to the alternatives of the multiple-choice questions and gives thorough rationale and justification.

To improve the quiz results and to help students in their assessment procedure, the learners are asked about the reasons of their failure right after the first assessment. Typical results of such a survey are given in Table 3.6. They concern both the students and the instructors.

Table 3.6. Typical reasons of student failure in quizzes

#	Reason	Improvement by students	Improvement by teachers
1	Low knowledge of the material	Preparation to discussion	Questions to be published in manuals and Internet
2	Weak English leading to misunderstanding	Upgrading English skills	Translation material into Estonian
3	Low discussion experience	Regular attendance and participation in discussions	Questionnaire improvement
4	Insufficient information about discussion	More activity in classes and at home	Publishing of results in the Internet

The following quizzes stabilise the learning progress. As a rule, most of the students respond correctly approximately to half of the questions and only few of them know all the answers. Undoubtedly, the results depend on the knowledge level established by both the mandatory and the optional learning resources.

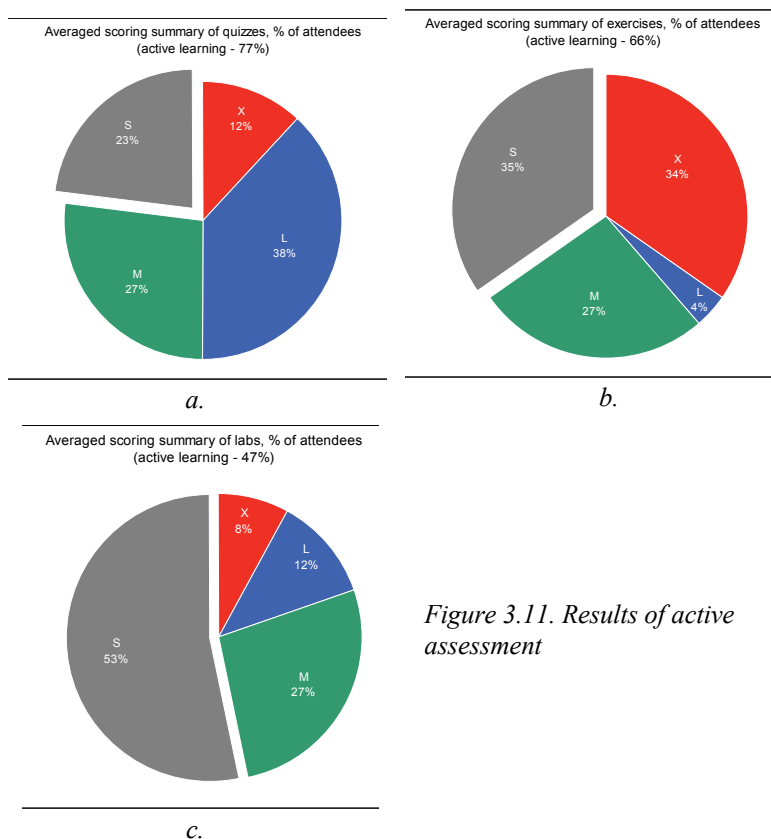


Figure 3.11. Results of active assessment

The classroom talks and discussions are used regularly as an important tool of learning monitoring and students' assessment. To ensure students' readiness for experimentation, an instructor asks usually 10 to 20 questions before, during, and after the work. Students are asked to find answers to the preliminarily published questions. Right answers increase the student's personal rating. According to the simple scoring principle, a student wins scores for each correct answer.

The principles of assessment throughout exercises were developed in the context of active learning. Though the full number of the lessons amounts to eight in the semester, only five of them are mandatory, whereas the remaining ones are optional. The number of problems to be solved in a lesson amounts to five on average. Again, solution of a sole problem in a lesson is mandatory, whereas all other problems are optional. The number of variants corresponds to the number of students. The scoring system assumes obtaining one score for each solved problem.

The laboratory works accessible by the students have been grouped into the three thematic blocks. Every block includes the mandatory and the optional works. In turn, in each work both the mandatory and the optional experiments can be conducted. Immediately after the experiments, an instructor and the students discuss the results obtained. This discussion touches both the correct and the incorrect responses and gives their justification. Again, the Internet assessment homepages help the students in their assessment improvement.

Analyses of the exercise and practice assessments resulted in the following:

- some students tend to approach the mandatory assessment level whereas many of them rush the optional level
- the reason of low scoring is the difficulty in the understanding of the optional level that requires additional time and knowledge
- the students of low motivation are more passive during the practice, therefore special attention to that group is required
- there is an evident dependence between the exercise and laboratory work scores and the examination grades

The students' final examination grades in Electronics and Power Electronics are calculated as the averaged scores obtained from on-lecture quizzes, exercises, and labs. If a student's rating does not exceed '3', at the end of the semester he/she takes the examination the grade of which is based on the examination question answers and the actual practical achievements. These practical scores count towards 20-40% of the student's total grade, with the remaining 60-80% granted for the traditional theory assessment.

Specific self-assessment modules were prepared as the combination of Web pages and Excel worksheets to provide students' self-assessment in Electronics, Power Electronics, and Advanced Course of Power Electronics. The objects include the rating tables like those shown above in Figure 3.12 accompanied by the students' self-evaluation rules represented in Figures 3.13 and 3.14.

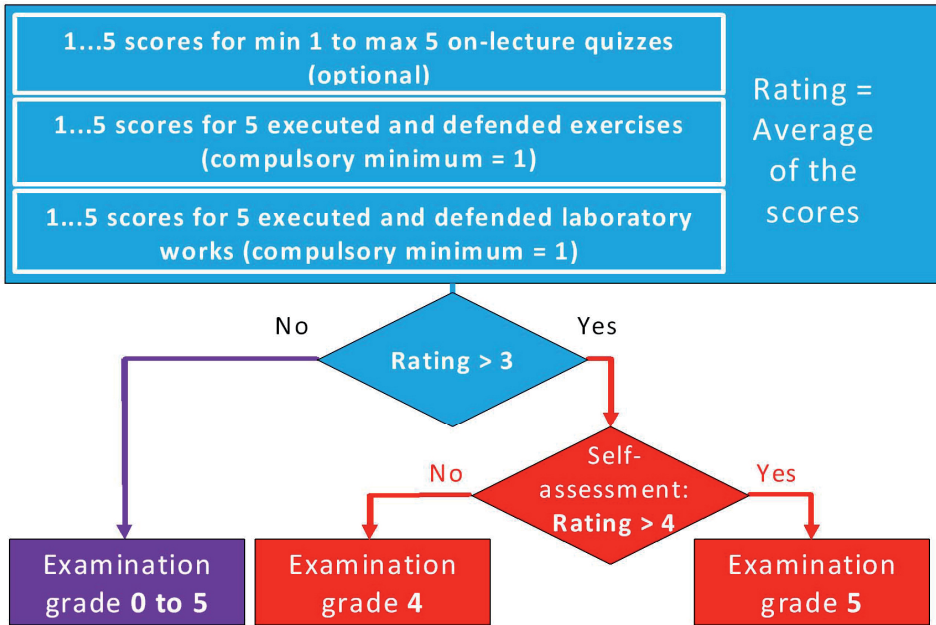


Figure 3.13. Self-assessment scheme in Electronics and Power Electronics

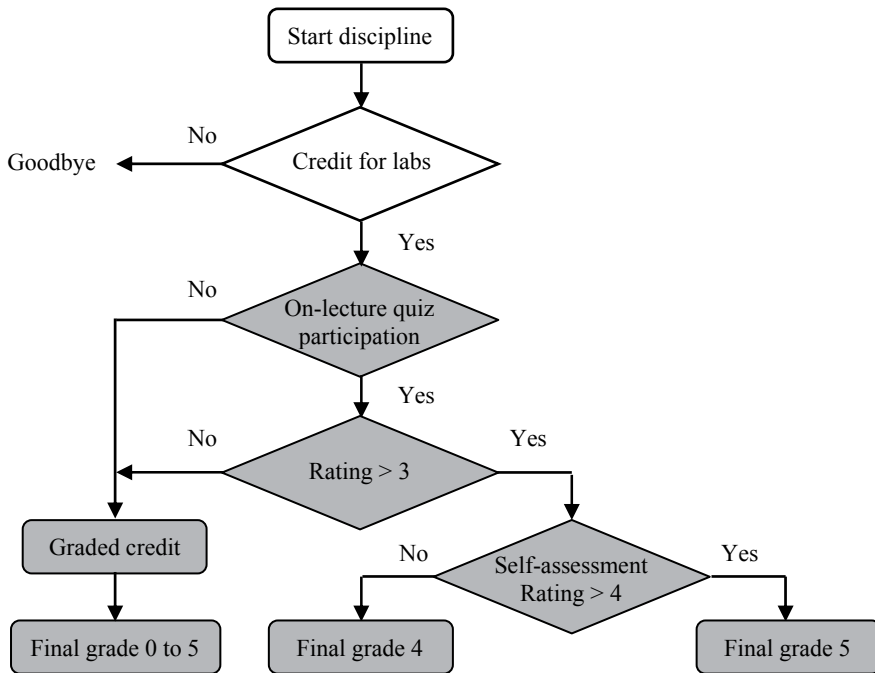


Figure 3.14. Self-assessment scheme in the Advanced Course of Power Electronics

As the learning process involves the mandatory tasks and the optional problems that add scores into the learner's rating, each object consists of three important parts: the results of the onsite lecture tests, laboratory assessment, and exercise assessment. During the semester, the students may follow online their current rating and their expected examination grade. Using these data, they obtain the tool to plan, adjust, and predict learning outcomes. Particularly, by solving additional tasks, they can improve their personal rating and their final grade.

Some assessment results are illustrated in Figures 3.11, b, c above.

3.4.4 Resume

1. The study shows that assessment in the context of active learning introduced into Electronics, Power Electronics, and Advanced Course of Power Electronics promotes learning and ultimately students' progress and achievement and has influence on what learners learn, how effectively they learn, and consequently on the quality of their learning.

2. The proposed scheme of assessment throughout the lectures includes initial introducing of assessment criteria, regular pre-lecture assignments, on-lecture quizzing, and summary-up discussions that help the students in their assessment improvement.

3. To provide self-assessment at the exercises and labs, only part of the full number of lessons is mandatory whereas the remaining ones are optional and in each work both the mandatory and the optional parts can be conducted.

4. Specific self-assessment modules were prepared as the combination of homepages and Excel worksheets to motivate students' self-assessment in the field that include the rating tables accompanied by the evaluation rules.

3.5 Summary of Chapter 3

As the traditional teaching has many drawbacks, to enhance student opportunities in knowledge and skill acquisition, an active learning technology was introduced at TUT into the courses of Electronics, Power Electronics, and Advanced Course of Power Electronics. It covers the novel format of the courses with the primary role of exercises and labs, the content deployment upon the two layers, namely compulsory material and optional issues, and the significant volume of the optional resources that engage students in their learning.

As a part of active learning technology, the model based approach to exercises makes the students responsible themselves for the circuit design and diagnosis, teach them to become experts in the circuits, and obtain a variety of experiences with most types of circuits. Five basic activities promote active learning and give constructive feedback between the students and the instructors, namely off-site preparation, in-class pre-work talk, performance in a lesson, in-class summing-up discussion, and off-site reporting, each included in mandatory and optional works.

An active approach to the laboratory practice includes the mandatory part executed in accordance with the traditional step-by-step instructions and the new optional part based on additional educational resources that stimulate strong students' efforts in their success in active learning. Thanks to the same five basic activities as the exercise lessons include the practice arrangement helps to develop such practical skills as the problem solution upon practical headings, effective calculations, experimentation performance, and equipment selection, and practical experience and qualification acquisition

The developed assessment methods in the active learning context introduced into Electronics, Power Electronics, and Advanced Course of Power Electronics promote ultimately students' progress and achievement and have influence on what learners learn, how effectively they learn, and consequently on the quality of their learning. To motivate students' self-assessment, the specific self-assessment modules were prepared as the combination of homepages and Excel worksheets that include the rating tables accompanied by the evaluation rules.

CHAPTER 4. ARRANGEMENT OF ACTIVE LEARNING FOR THE MASTER'S STUDY OF THE ADVANCED COURSE OF POWER ELECTRONICS

4.1 Remote Laboratory for Active Learning on the Master's Level

4.1.2 Proposed architecture of the remote laboratory

A bandwidth of a usual laboratory is limited by the physical space. The timetable constraints encumber the working students whereas the handicapped students have difficulties attending the lab. The extramural students that live far from the host university as well as the part-time students need to work on a degree without travelling, thus the remote laboratory suspects significant social and economic benefits as well. To overpass these restrictions, part-time, weekday, or evening student work is used. At the same time, the students and teachers obtain the Internet in their communication intensively; therefore, it seems natural to enable their remote collaboration in the Power Electronics laboratory via the Web.

The goal of the remote laboratory in Advanced Course of Power Electronics is to allow the students remote access to experiments on the real laboratory setups. The corresponding hardware can be achieved in different ways [0609].

As the first step, a simple approach was taken at TUT based on the remote desktop for the distant control of existing workstations in the laboratory [Z08]. The laboratory setup contains the ware required for experiments, such as target boards and measurement equipment. The remote desktop software supports this approach. The main drawback of such an approach is a peer-to-peer matching of the local and remote clients. Therefore, the proposed architecture is considered as the preliminary stage only, which should be replaced by more progressive client-server topology. Nevertheless, as all the software is bound to the workstations, there are no additional problems with licenses or software distribution. Using the existing software for remote control, the setup of a distance lab requires minimum hardware and program modifications.

The remote educational environment is usually developed targeted to the specific laboratory setup [0814]. Designing the course for the remote laboratory, which will also be available for students from other institutions, some additional requirements have been met [0818], [0825]. First, the experimental topics address the up-to-date problems interesting for the wide range of engineering students. Second, the experiments are prepared in the way that the students with diverse knowledge backgrounds, various prior knowledge and experience, and different problem solving approaches would be able to do successful work with minimal intervention of a teacher. Further, a sufficiently flexible work structure was developed so that the teachers from other institutions and local teachers can adapt it to their needs [0507]. The proposed distance learning approach was designed to be used in conjunction

with the usual professional training procedures, such as lectures, exercises, and on-site laboratory works.

Below, the concept of the remote laboratory work *Computer Examining of ACS800 Electric Drive* is given. It is based on the *DriveWindow* software of ABB, the Windows application for commissioning and maintaining the ABB drives equipped with fiber optic communication, which provides remote connection. The specific ISA or PCMCIA card is used to process the online operation. The software function list includes control operations (start, stop, references, etc.), signal monitoring, changing parameter values, control, and display of data and faults, backup and restores operations as well as the network functions.

An objective of the work is to maintain and learn ABB drives using the *DriveWindow* soft tool. The aim is to master the converter remote control, its signal monitoring, working with parameters, and graphical trending. To execute a laboratory work, the tutorial aid in Advanced Course of Power Electronics was developed.

The work starts by running a laboratory computer and a user logging. Students search the computer name and permit other users the remote connection to this computer. They check the connection status and speed and find out the computer IP address as well. Further, the remote computer is running and the *Remote desktop connection* window opens. Then the student follows the name or IP address of the laboratory computer, connection and logging that are provided.

Next, an acquaintance with the user interface of the *DriveWindow* shown in Figure 4.1 is made. The interface includes the standard Windows areas which a user edits, moves, drags, and resizes by the keyboard and mouse. Students are asking to switch on the testing drive and to connect the *DriveWindow* to the drive. They study the main panels of the user interface, such as the title bar, the menu bar, the toolbars including *Standard* toolbar, *Monitor* toolbar, *Logger* toolbar, and *Drive* panel, the status bar and the window area divided into four panels – *Browse tree* and *Item sets* on top as well as *Trend settings* and *Trend display* below.

To control the drive, either the *Drive* panel or the *Drive* menu can be used. The status bar describes the user actions. A student executes the following operations:

- selects the drive in the *Browse tree* pane
- takes the control by toggling the *Take/Release Control* button
- examines the status image, name, and address of the currently controlled drive
- resets the fault and clears the fault logger if an error occurs
- assigns given reference frequency (30...70 Hz) into the edit field and sends it to the drive by the *Set Reference* button or *Enter* key
- runs the drive and further stops it
- changes the motor direction of rotation and runs it again

- executes the coast stop
- releases the control and ensures the drive is adjustable from the control panel

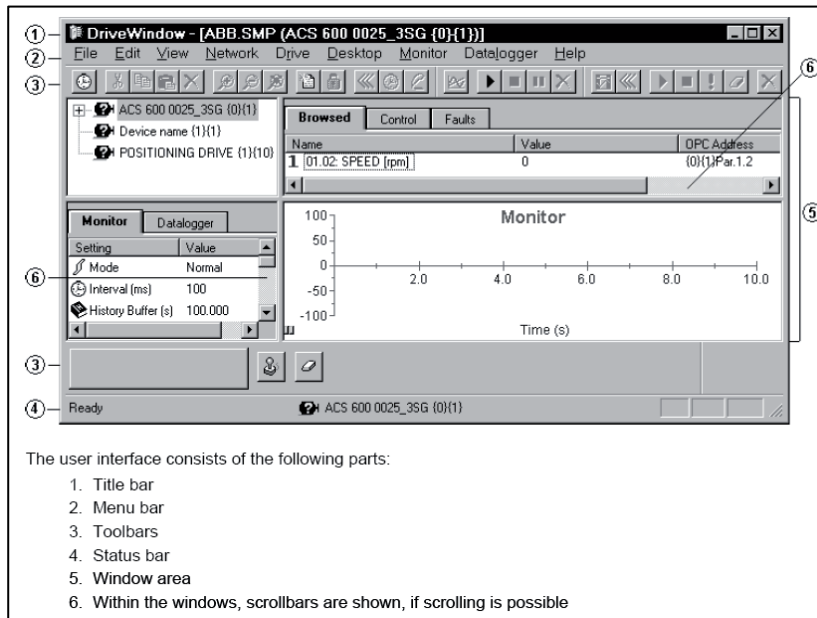


Figure 4.1. User interface of DriveWindow

The next step is devoted to drive monitoring. To monitor the control, the learner uses the *Monitor* toolbar or the *Monitor* menu. The system runs and collects data by reading cyclically the items from the drive in real time. On this stage, a student performs the sequence of the control operations:

- take the control
- to learn the drive acceleration, a user chooses *Parameters* in the *Browse tree* panel and sets the parameter *Acceleration time* to a given value (5...15 s) in the *Item Sets* pane
- in the *Trend Settings* pane, a user sets *X-Axis Length* above the given acceleration time
- to add the motor voltage, current, and frequency for monitoring, a user chooses *Actual Signals* in the *Browse Tree* pane and drags the required strings into the *Trend Settings* pane; the numeric images appear in front of the added items whereas *Delete* button lets to remove unnecessary items from monitoring
- to start monitoring, a user clicks the *Start or Continue Monitoring* button in the *Monitor* toolbar and right away runs the drive to the given reference frequency

- a user waits until the running comes to the end and presses the *Stop Monitoring* button; then he/she stops the drive
- to scale the trends swing, the *Adapt Y-Axis* from the *Axis* submenu or *Autoscale* from the *Scaling* submenu of the *Monitor* menu are used
- while viewing the stopped or paused trends, a user clicks the drawing area to display the graph cursor which measures the items

Saving and analysing the results is the last stage of the work. There are several ways to save trends. The currently displayed trends can be saved from *File* menu into a *DriveWindow* graph file, exported to a text file, copied to the clipboard, or printed.

- to process the data, a student chooses *Export* in the *Graph* submenu and assigns a name of the created *.txt* file which is later opened by *MS Excel* that recalculates per-unit data into Volts, Amperes, and Hertz, and builds the required diagrams.
- to save the trends that allow the work proceeding, a user selects *Save As* command, names, and comments the new *.dwt* file which may be restored in the future by double clicking or selecting *Open* command in the *Graph* submenu.
- to employ the trends in other applications, a student should copy them into the clipboard using *Copy Graph* command in *Edit* menu and paste them into the required software.
- to print the trends when the current printer is unavailable, the *Microsoft Office Document Image Writer* may be used.
- after the successful saving, the monitor can be cleared by the *Clear* button and *Acceleration time* restored

An individual student report contains:

- scaled diagrams of voltage, current, and frequency timing traces
- mutual voltage/frequency diagram built using the voltage and frequency data
- output voltage/current diagram built using the voltage and current data
- conclusions concerning the results estimation and explanation

4.1.3 Benefits and drawbacks of the remote laboratory

The e-laboratory promises the students to acquire the methods, skills, and experience related to the real equipment in a manner that is very close to the way they are being used in industry. Thanks to e-learning, the teachers of distance Power Electronics courses may interact with the students and the specialists working in industry and can utilise their practical experience and knowledge to improve the applicability and quality of the course.

The rules and guidelines proposed by this work are flexible enough, therefore the students may choose when and where they participate in the course requirements.

Since the laboratory results are recorded, the students can replay certain parts that may be slightly more challenging. They also have the flexibility to schedule breaks and pauses, to catch up with the notes, and to fit in their individual learning styles and preferences.

The proposed approach suggests a number of other benefits in learning:

- allows students to keep their current job conveniently while taking a course [0506]; with the technology available today, this is possible even if the student lives across the country from the school, in a small town, or in remote location
- promotes the sharing of the Power Electronics laboratory among different Estonian and foreign institutes, thus allowing the students to practice laboratory facilities remotely without having to physically travel to Tallinn, as [0301] recommends
- allows remote experiments by the students along with the scientists and experienced researchers [0614]
- enables student learning in a collaborative manner by remote participation with other students
- combines on-site activities performed within the real lab during the normal practical sessions with the online one performed remotely via the Internet
- increases the “touch time” for expensive equipment that may be shared
- allows students to perform their experiments safely using simplified guidance
- overpasses the working laboratory place and time limitations for the users
- improves an experience in measurements, observation, and result evaluation [0701]
- helps to use new media and information technologies in the classroom both making learning more attractive to the student and teaching much easier [0702]
- gives more freedom to the students and tutors to analyse and discuss the results of the measurements and tests

The drawbacks of the discussed e-learning technology may be divided into two main groups – social and technical.

Social problems. Education is a deeply human-interactive process being accompanied by the collaborative activity. It is a great historical tradition to pass knowledge by teachers from generation to generation, thus the role of a teacher was of main importance in overall human history. Collaborative learning theory contends that the human interaction is a vital ingredient of learning. Consideration of this is particularly crucial when designing e-learning, realising the potential for the medium to isolate the learners. With well-delivered synchronous distance learning and technology like the message boards, chats, e-mail, and

teleconferencing, this potential drawback is reduced. However, the e-learning detractors still argue that the magic classroom bond between a teacher and a student and among the students themselves cannot be replicated through the communication technology [WL13].

Today, only a few e-learning systems include the rich, authentic people interactions. In the most environments, the participants do miss instructors and classmates in e-learning [0203].

This statement concerns the student-to-student interaction during the learning as well. In other forms of education, the students can network and clarify doubts with their colleagues, making it easy to obtain different views on the same query. This is absent in e-learning, as a student depends only on the given subject materials for clarification and there is little or no interaction among the students and the company officials [WL12]. Reduced social and cultural interaction seems to be a significant argument against the ungrounded transfer to e-learning. The impersonality, suppression of communication mechanisms, such as body language and elimination of direct learning that are part of this potential disadvantage, decrease all advances in communications technologies.

So far as e-learning is not only an educational but a technological process, an inappropriate content for e-learning may cause additional problems aggravating the situation. Even the acquisition of skills that involve the complex physiological or emotional components (for example, juggling or mediation) can be insufficient for e-learning implementation. In this connection, the cultural acceptance should be an issue in the organisations where student demographics and psychographics may predispose them against using computers. The technology issues of the learners are required, most commonly concerning technophobia and immunity to the required technologies.

Moreover, until recently sharing knowledge over the Web had three additional legal drawbacks [WL16]:

- faculty is often unable to control the dissemination of its material
- sometimes, faculty has the problems in attaching the usage conditions to the learning resource offerings
- faculty does not get rewarded for the learning resources offered

As a result, the reduced social interaction may have grave consequences. The study shows that e-learning may be effective if and only if the usual peer-to-peer communication between the teacher and the student is impossible or restricted significantly. In the other cases, the result of e-learning cannot exceed the result of the direct teacher-to-student contact.

Technical problems. The technology issues are required that have to predict whether the existing infrastructure can accomplish the training goals, whether the additional technology expenditures can be justified, and whether the compatibility of all software and hardware can be achieved.

Portability of training has become the strength of e-learning with the proliferation of the network linking points, notebook computers, and mobile phones, but still does not rival that of printed workbooks or reference material. Though much e-learning environment is praised and innovated, a worldwide experience proves that computers will never eliminate completely the human instructors and other forms of educational delivery, especially in engineering. What is important is to know exactly what e-learning advantages exist and when these outweigh the limitations of the medium [WL13].

In addition, some technology issues during learning can prove a bane in e-learning. The existing technical infrastructure may not be able to achieve the training goal. It can be as simple as a slow net connection or non-compatible software. Quality is the issue here. It takes time, resources, and skill to deliver all the necessary content options fast and effectively. E-learning technique must be careful and elegant. Nevertheless, live or synchronous e-learning plays the role of a major cost saver in the most of modern educational applications [0203].

Contemporary e-learning equipment cannot bring into play all human sense organs. As usual, the only eyesight is used to acquire the learning information that is the significant drawback in engineering education, where such factors as noise, smell, and perceptible influences are of great importance.

The limited bandwidth presents a special problem when designing Internet-based education with multimedia. The connection speeds can be slow and downloads can be long due to the factors which the trainers often have little control over. Until the bandwidth improves, the e-learning developers often need to exclude most of the "fat media" in their delivery systems, especially video, or create a hybrid design. The visually rich, highly interactive medium, and sophisticated authoring tools of the CD/DVD-ROM era is to be replaced with the bandwidth constraints of the Internet and authoring limitations of HTML. The consequence is that the idealism of multimedia is presently much greater than its actuality. However, the experts predict that this situation will improve in the future with the new technologies, such as broader bandwidth and greater compression rates developed for delivering audio and video [0001]. Therefore, an Internet laboratory cannot now be used to study the fast physical, electronic and electrotechnical processes as it normally gives the wrong experimental results.

Clearly, the up-front investment required of an engineering e-learning solution is larger due to the development costs. As a result, the budgets and cash flows will need to be negotiated.

4.1.4 Resume

1. As the bandwidth of usual laboratories is limited by the physical space, the timetable constraints, and by the attendance restrictions of some groups of students, thus it seems natural to enable the student-to-teacher remote collaboration in the Power Electronics laboratory via the Web.

2. The proposed concept of an e-laboratory and the set of computer-based laboratory works in Advanced Course of Power Electronics open the possibility to study via the Internet, providing a number of benefits to both the students and the teachers, though the proposed architecture is considered as the preliminary stage.

3. The e-laboratory promises the students to acquire the methods, skills, and experience related to the real equipment in a manner that is very close to the way they are being used in industry helping the teachers to interact with the students and the specialists working in industry, and utilising their practical experience and knowledge to improve the applicability and quality of the course.

4. The drawbacks of the discussed e-learning technology may be divided into two main groups – social and technical, the former due to the reduced social interaction, and the latter because the e-learning equipment cannot bring into play all human sense organs.

4.2 Problem-Based and Project-Based Learning

4.2.1 Problem-based approach

People interpret new experiences and knowledge in terms of the particular concepts already presented in their memory. Prior knowledge and perceptions influence the appreciation and construction of the new concepts. For conceptual change to be achieved, the knowledge requires rebuilding. To construct new conceptions that better fit the case and then replace the prior knowledge, the learner should be given opportunities in solving the scientific problems in order to internalise it and to develop skills using them correctly and scientifically.

In the studies of engineering education, engineering learning is displayed in a rich context of experiences based on the abstract information, hands-on experiments, social activities, community discussions, and real problem solving among other forums. Numerous references and experiences show that the problem-based and project-based learning are the best way to immerse a student into the skills required by employers that encourage the recruitment of more engineering graduates. They represent the prospective directions of the contemporary engineering education [0303], [0501].

Problem-based learning called also *learning by exploring* is an approach in which learning is linked to applied research and development projects to encourage students to learn through the structured exploration of a research problem [0804], [0810]. Reworking the traditional lecture and tutorial, students define, carry out, and reflect upon a research task, which can often be a real-life problem. The tutor acts here as a facilitator and resource person to whom they can meet for an advice or guidance.

Problem-based learning involves a range of pedagogic methods that stimulates students to learn through the structured exploration of a research problem, which is concerned as a starting point for the acquisition and integration of new

knowledge [9802]. The student's learning process is stressed by a problem to solve in which the student discovers what to learn and how to do it. This strategy gives students the challenge of “learning to learn” through the resolution of open problems, being guided by a teacher as an enabler providing resources and offering advice while they advance in their research. Here, the tutor role changes from being the sage to being a guide in the process of finding a solution. The tutor provides hints and encourages the students to seek the information and knowledge sources. The students collect and analyse data, make discoveries, and report the obtained results. Teaching and facilitation are oriented here to the wide range of explicit learning objectives. Some of them can be precisely focused to the specific content of the theme. The students can achieve additional goals as they explore complex themes along different lines. They learn to learn collectively, learn how to help their partners and give constructive feedback for both them and their team members. Therefore, this working practice depicts a consistent alternative with the teaching method needed for training professionals, especially technicians [0817].

In [0817], some examples of the problem-based learning in power electronics are given. Effective methods of the design of different kinds of power electronic converters are proposed to control ac and dc electrical drives fed by industrial mains and battery supply. The typical design stages concern mechanical computation, equipment selection, electrical power calculation, and circuit development. The research part deals with the transient evaluation followed by the fine controller tuning and optimisation. Simulation provides the steady state and dynamic responses as well as the calculation of the electronic components.

The problem-based learning process starts by identifying the final problem or the research object, analysing and describing it, and selecting the appropriate work methods. The work represents a continuous problem-solving process, focusing on research, development and generating the new competences [0822]. The outgoing result is a creation of a novel operating method, a model, a service or a product. The new outcomes may be reached in the following ways:

- motivating the students to become interested in the subject
- assisting students to master the fundamental concepts
- fostering critical thinking
- forming and testing hypotheses
- finding the problem solving strategies and techniques
- mastering research and development methods
- teaching students how to learn and acquire lifelong learning skills
- ensuring that exploring is attuned to the world of work

Availability of a complete set of the learning objectives is crucial here to determine the direction of the work, acting as incentives both to reach the desired solution and to acquire a range of knowledge and skills while moving towards this solution. Also, at times, more learning objectives are added while work is in progress. For each problem, the students are encouraged to distribute the work

amongst themselves to search for information from various resources along with compiling the data, doing calculations, performing experiments, finally recording the work done and preparing a presentation.

The significant advantage of this active methodology is that the students learn very important professional skills, like how to search information, acquire the new data, solve problems, build new knowledge, and deeply investigate the subject of the problem, not only to learn basic theoretical concepts.

4.2.2 Project-based learning

Project-based learning, called also *learning by doing*, is a student-centred projecting strategy that fosters initiative and focuses a student on authentic real-world open projects that can increase motivation for the majority of students and enhance their education [0608], [0806], [0810], [0909]. One aim of this approach is to arrange the courses so that the students would be motivated to study. This instructional method challenges students to participate in engineering projects and to develop skills in collecting and evaluating the information needed for gaining professional experience. Using this approach, the main project steps are introduced into describing a problem, specific solutions, and making the implementation in a real platform. Choosing a people-centric engineering project to improve their community, the students become familiar with the social aspects of their future job. These aspects are an important part of making technical appealing to new generations and have the advantage of allowing the students to develop other professional skills, such as leadership, teamwork, and decision-making analysis.

To develop the project-based learning at TUT, experience of many institutions was used, for example, the 25-year experience of project-organised undergraduate education based on a unique pedagogic model of teaching gained at Aalborg University, Denmark. In this method, a large part of semester teaching and student work revolves around the complex real-life problems or issues that the students consider and try to resolve while working together in groups [0809]. Similarly, the curriculum structure proposed in [0608] was applied. It consists of eight courses: four theoretical courses and four project-based courses (including a compulsory master's thesis). An important result is that all students have developed effective systems, while considering that the results are worth the effort invested.

During this work, cooperation with the particular researchers and scientific institutions is usually initiated. The researchers make observations in the problem-based activity and give feedback to the instructors on a regular basis, survey the students' opinions and prepare questionnaires for the students to fill in and assess the course [0821].

Accordingly, assessment in the project-based learning invokes to evaluate:

- problem statement and understanding
- learning objectives
- the methodology used

- problem solution under the practical headings
- calculations, simulation execution, and software selected
- practical outcomes, presentations, and the printouts prepared

On the other hand, a drawback of this method is that it requires more time to cover the same amount of knowledge than a classical approach. It is not easy to implement such style, especially without the face-to-face settings. Moreover, the cost of this kind of the knowledge acquisition is higher, and the number of students in each group needs to be reduced. However, with the more realistic syllabus based on information technologies these drawbacks tend to be minimised.

4.2.3 Composite project in the Advanced Course of Power Electronics

To execute active learning on the master's level, both approaches have been joined in the composite course project in the Advanced Course of Power Electronics (AAV0050) [Z13]. It is the master's study optional course provided by the electrical engineering curriculum. Course duration is 16 weeks, consisting of three contact hours per week and at least three hours of weekly independent work.

As with any engineering discipline, Advanced Course of Power Electronics is based on the integration of numerous fields of knowledge. Insofar as a certain number of systems with the components of different nature are merged, a conflict between technological complexity, cost, and simplicity of maintenance naturally occurs. The corresponding educational aim is to teach specialists working at the intersection of electronics, mechanics, and control. Course assignments and master's theses are suitable tools for this kind of training.

The learning outcomes for the numerous subjects in the master's training program have been listed by the researchers and industry agents. Senior engineers from various industries were contacted for their ideas regarding suitable industry relevant projects for the master's students. Following a series of industry meetings and feedback, suitable topics were specified. The modules were designed, built and tested by the researchers. Then the specification sheets were handed to the students at course start. The projects are designed in a modular fashion, so that any independent module can be completed during the course that the student has enrolled in. The independent modules are assessed by the instructors teaching the course.

The master's students are expected to design, build, and test various modules as specified in the projects within a period of some months. In some projects the students work individually, in others they are joined in groups while working on the project. They have to use the theoretical knowledge in Electronics and Power Electronics and Computing Engineering, Mechanics, Automatics, etc. gained during their bachelor's and master's study. On completion of the project, students' learning experience and learning outcomes will be used to prepare their master's theses. The students' practical skills are assessed while working on the project, and their theoretical knowledge is graded on a written exam after the project completion.

To implement the composite problem-based and project-based learning, the traditional style of lectures was changed so that the behaviour analysis would replace partially the formal explanation of the theory. In the lectures, the problem scenarios are presented to the students before any relevant theory or practice is given. The open problems are framed by the teacher in accordance with the topics in the syllabus and a lecturer acts as a contractor similarly to the problem-based approach. He/She asks the students (acting as subcontractors) to design and implement a fully functional motor drive with an electronic converter that covers most of the topics reviewed in the theory lessons. The first classes are spent creating a systematic design of the final product – the specifications and main functions are described, and a functional block diagram is conceived. This policy means that students find the explanation of systems and ideas to be useful because they can see the target application. In addition, the start-to-finish design, from the block diagram until the final implemented system, helps the students in the task of determining, solving and grasping the problems. Another benefit is that the students must pay particular attention in the classes in order to complete the proposed prototype. During the next lessons, the lecturer reviews the designs and products and advises the students about the possible errors or mistakes. Therefore, the teacher is responsible for ensuring that each student's design is correct and that the final prototype is a working unit. Finally, he/she also acts as a vendor as the final prototype is usually implemented on the prototype boards.

An engineering goal of the project is to build an effective system using the components proposed by many world companies. Successive assembling of electrical drives with power converters can solve the problems owing to rather complicated algorithms. Here, the mechanical, electrical, electronic, and power engineering problems are encountered in close integration. The procedures of a motor drive and power electronic converter design involve a number of complex tasks. Some of them are as follows (Figure 4.2):

- timing calculation and construction of the mechanism travel diagram
- computation of mechanical forces and synthesis of the torque/power patterns
- dimensioning and selection of the gear and motor
- choice and checking of an optimum motor-gear set
- dimensioning and selection of a power electronic converter or design of the new one
- building of the motor drive and power converter wiring diagrams
- development of controllers for the multi-loop control and adjustment
- process simulation along with the analysis of the steady-state diagrams and transients
- economic considerations and efficiency evaluation of the project
- report generation, presentation and defence of the obtained results

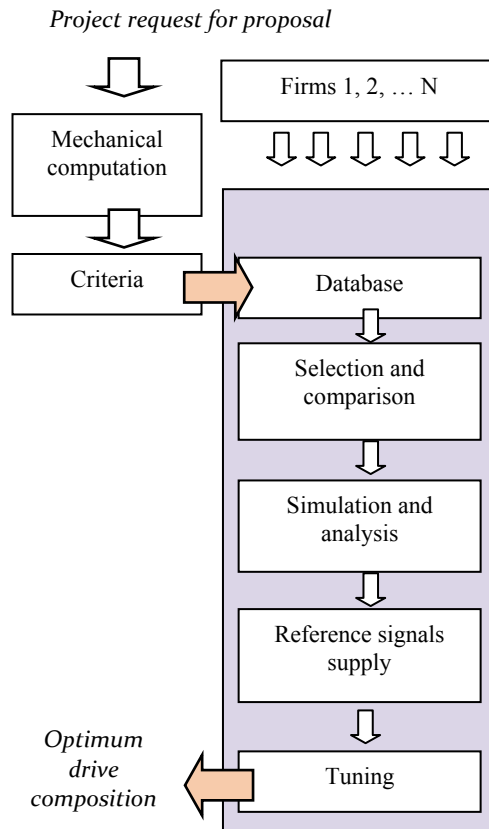


Figure 4.2. Block-diagram of the project mastering

As different from the companies which manufacture and propagate their production, the proposed approach is addressed to the overall equipment selection, tuning, and optimisation process independent of company interests.

To this aim, the specially prepared software system transfers data from a variety of databases into the uniform data source (Figure 4.3) with the specific data management system, which provides the search and updating the data from the open-access corporative databases.

The design process starts from the load computation using the project developers' own experience and methods. Further, a student selects a group of gear types from different companies using the results of the load calculation. Through these gears, the forces and mechanism speed are converted to the equivalent values on the motor shaft. Then, the particular motor type that matches each gear type is to be selected based on the converted forces and speed. Thus, a set of permissible drive variants is generated. Once the equipment framework is found, the new problem appears – which of the suitable motor-gear combinations is optimum? To find a

solution, a designer can form appropriate criteria and sort them. It may be a criterion of maximum accuracy or speed, minimum weight, power, or inertia, highest rigidity, etc. In this way, the whole scale of the electromechanical and electronic properties is collected, from which the choice is done based on judgments about preferences of that or another criterion. Then, simulation of the open-loop system is conducted using the standard or the original simulation software. On the next stage, the power electronic converter equipped with a control system which includes some regulators and sensors is designed or selected. Their transfer functions, gains, factors, and time constants are calculated to meet the standard settings. Then, the closed-loop system testing is carried out on the model and its optimisation is executed, if necessary. This approach is more suitable for the educational targets thanks to its universality.

Sheet	Capacity, W	Contents
caABB	370-22000	Frequency converters ABB
caALTIVAR	180-630000	Frequency converters SCHNEIDER ELECTRIC
caDANFOSS	1100-45000	Frequency converters DANFOSS
caDELTAELECTRONICS	400-45000	Frequency converters DELTA ELECTRONICS
caLG	30000-160000	Frequency converters LG
caOMRON	100- 300000	Frequency converters OMRON
caSEW	400-75000	Frequency converters SEW EURODRIVE
caSIEMENS	120-75000	Frequency converters SIEMENS
caNEVAELECTROMASH	400000-1250000	Frequency thyristor converters NEVAELECTROMASH, RUSSIA
caVACON	250-3000000	Frequency converters VACON
cdMAXON	50-500	DC converters MAXON
cdBTU3	1000-45000	DC thyristor 3-phase rectifiers RUSSIA
cdBU2	500-6000	DC thyristor 2-phase rectifiers RUSSIA
csALLEGRO	2-90	Step motor drivers ALLEGRO
csCONTROLTECHNIQUES	350-1000000	Servo converters CONTROL TECHNIQUES
csETS	3000-8000	Servo converters ELECTROTECHNICAL SYSTEMS
csMAXON	120-850	Servo converters MAXON
csMITSUBISHI	30-7000	Servo amplifiers MITSUBISHI
gp	60-315000	Planetary gears RUSSIA
gpMAXON	500-50000	Planetary gears MAXON
gs	1110-18000	Ball-screw gears RUSSIA
gt	60-98000	Spur gears RUSSIA
gw	10-4220	Worm gears RUSSIA
ma4A	1100-45000	Induction general purpose motors RUSSIA
ma4AK	5500-22000	Induction wound rotor motors RUSSIA
ma4AP	600-13000	Induction multispeed motors RUSSIA
ma5A	370-200000	Induction general purpose motors RUSSIA
maABB	55-630000	Induction general purpose motors ABB
maSIEMENS	11000-200000	Induction motors SIEMENS
md2PN	220-39000	DC general purpose motors RUSSIA
mdDK	70-7700	DC high-torque motors RUSSIA
mdMAXON	150-250	DC motors MAXON
mdMIG	40-9000	DC pancake motors RUSSIA
msCONTROLTECHNIQUES	300-12000	Servo motors CONTROL TECHNIQUES
msDEMZ	350-6600	Servo motors DEMS, UKRAINE
msMAXON	15-400	Servo motors MAXON
msMITSUBISHI	30-7000	Servo motors MITSUBISHI
msSEW	200-20000	Servo motors SEW EURODRIVE
mstMAXON	10	Step motors MAXON

Figure 4.3. Database window

A specially prepared textbook [0824] contains sections that support project-based learning. Some of them are intended to complement the lectures for beginners and for advanced learners, summarising basic terms and conditions as well as the topical mathematical bases of the course. Other parts explain the broad self-learning part of the course. Calculation examples, experimental and assessment problems of the course are also provided. The numerous links connect the textbook with analogous and supplemental assignments in the field. The properly structured index and the reference list serve as the powerful navigation tool.

As a result of the composite problem-based and project-based learning, the staff, students as well as the community have benefited. Industry relevant projects provide students with knowledge of how theory can be related to current industrial practice. Students show a lot of interest and enthusiasm while working on projects. The work gives a holistic approach to student learning as it integrates the commercial projects with the core courses and learning objectives. Students' technical skills are tested when working on designing, building and testing the project. While designing the project, the students integrate and connect knowledge from various courses to work on an optimised solution for the mentioned problems in the project. They have to know the background theory and consider all practical issues while designing.

4.2.4 Resume

1. The problem-based and project-based learning approaches encourage the reinforcement techniques that focus on a conceptual understanding and new opportunities for students to choose the content and study methods, thus showing students that teaching is stimulating and caring and giving them time to process the concepts in contrast to overworking within the course or curriculum.

2. An underlying principle of the described environment is the coursework arrangement directed to designing optimal application-specific equipment with power electronic converters based on the active learning approach.

3. The presented industry-relevant course project performed in the curriculum illustrates the effectiveness of this method an important result of which is that the students acquire knowledge and skills to design more complex and sophisticated electronic systems, learning effectively the problem statement and understanding, task solution under the practical headings, as well as the result presentations.

4. Problem-based and project-based learning are mainly beneficial for the graduate courses that are usually targeted towards the final-year master's engineering students that are ready to start their final dissertations, though some of its components may be effectively used in bachelor's training.

4.3 Collaborative Learning

4.3.1 Benefits of collaborative learning

Students may engage in learning when they enjoy connecting with others. To collaborate, individuals should share information (communication), organise themselves (coordination), and operate together on a common space (cooperation). The exchanges that occur during communication generate commitments managed through coordination of the jointly executed tasks. Collaboration is impossible without competition within our society, life, and work.

Employing competitive learning has a complementary potential to engage students. Once they are faced against each other, their competitive instincts can encourage them to increase their commitment towards the learning process. Even students who initially are not inspired by the subjects may begin to be interested once they have to compete. This is particularly useful for students who are not prone to be competitive, since they should be confronted with this reality as soon as possible.

As the development of communication skills is one of the main goals of engineering education, EHEA proposes an integrated student-centred collaborative learning, called also as teamwork or a team-based learning. Collaborative learning is an educational method where students work in the small self-directed teams to define, carry out, and reflect upon a research task, which can often be a real-life problem [0101], [0706], [0804], [0812], [0822]. Arranging students in groups, which are assigned specific tasks, problems or projects, is a successful way to enhance communication. Similarly to the problem-based and project-based approaches, the tutor acts here as a facilitator and resource person meeting for advice or guidance. This methodology emphasises cooperation and creating team learning and developing culture and makes it possible to include and use various scientific perspectives and methods of learning, research and development in operation and action. Group projects are being increasingly used in higher education in general, because they do not only facilitate the intellectual and social dimensions of education, but also mirror industrial approaches to solving the problems. Such projects promote discussion between the team members, i.e. in-group communication. Project presenting in oral sessions serves as a tool to disseminate student work between themselves. In addition, the group project approach in in-group and inter-group dimensions opens up the possibility of peer assessment, which constitutes an interesting experience for critical thinking and analysing.

4.3.2 Implementation of collaborative learning

Collaborative learning has become a necessary part of the project-based and problem-based approaches. To stimulate teamwork, a specific team-based methodology has been developed. The goal of the collaborative design is to build collectively effective real-world electromechanical equipment.

One of the typical course works is devoted to the design of the converter-fed drive system for a robot. The schematic plan of the transportation robot is given in Figure 4.4.

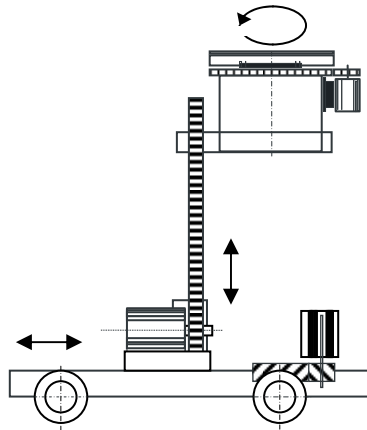


Figure 4.4 Schematic plan of the transportation robot

The driven equipment includes three mechanisms – a carriage, a hoist, and a rotary table. The types of gears, motors, and power converters for the particular learning problems should meet the demands given in the request for a proposal. The project variants propose four types of gear – spur, planetary, ball screw, and worm. Three types of electrical motors can be used – asynchronous, synchronous servomotors, and dc machines. Three types of power converters may be selected by the designers – transistor ac/ac and dc/dc converters, and thyristor rectifiers.

The work includes two stages: the stage of individual creativity and that of collective work, particularly via the Internet. These phases are detailed in Table 4.1.

Table 4.1. Stages and disciplinary bases of design

Stages and items	Disciplinary base
Individual design stage	
1. Force, torque, and power computation	Mathematics, Physics and Computer Science
2. Equipment selection	Database Theory
3. Optimisation of the electrical drive content	Function Analysis and Control Theory
4. Synthesis of regulators	Discrete Mathematics and Control Theory
Collaborative design stage	
1. Composition and interrelation of mechanisms	Electrical Drive and Power Electronics
4. Estimation of the project	Function Analysis, Reliability, and Economics

The first and the last part of the project is the collaborative design. First, the intercommunications of the robot sub-systems are organised. The final, most important part of the project, concerns an integration of the various modules and testing the overall functioning of the system.

On the individual stage, every student designs a converter-fed drive of one of the mechanisms from the composite project described in the previous section. For the forces, torques and power calculations, the data of the related mechanisms are required, thus co-operation is needed to obtain a successful result. Effective selection of the components depends on the joint efforts and personal solutions. The same concerns the overall estimation and the project assessment.

Students learn about project management when they work on resources, timelines and procurement of components. The generic skills are tested based on students' attitude when working in teams and submitting the technical report on the project. Hence, the project development covers all the aspects of learning.

A student group comprises usually 6 to 15 participants, randomly shared into 2–5 interaction-oriented teams with a proper mix of both academically weaker as well as stronger students. This grouping is done at the beginning of the course when the learners are informed about the practical set of the discipline that would require the study of real world systems and that the teams are a key component of the project. For each problem, the team is encouraged to elect a leader who would organise work distribution. The team leaders are appointed by the course lecturers to coordinate group activities and ensure close interaction among all team members. All teams are charged to meet regularly and to achieve the set objectives on the event driven basis. The students are assigned 12 weeks to work on the research problem. They distribute the work amongst themselves, with team members performing tasks, such as searching for information from various resources, compiling the data, doing calculations, performing experiments and finally recording the work done and preparing a presentation. Ideally, these various tasks are rotated among the team members. The teams discuss issues, decide their own theoretical, practical and software goals and explore these learning and mistakes. This encouragement is given by continuous monitoring and by instructing them to record each relevant finding, any mistakes committed and the corrective action taken. Once the team members reach the solution, they are also asked to frame similar kinds of problems and identify application areas. Throughout, they are guided by an instructor who would correct students as they encounter difficulties and help them to draw conclusions to reach the desired goal.

The project is worth 30 to 50% of the final grade and the remaining 50–70% is covered in the course examination. The criteria used to score the students in the project are listed in Table 4.2.

Table 4.2. Scoring criteria

Item	Score, %
Problem formulation	3 – 6
Team participation	5 – 10
Minutes of meetings	5 – 6
Report	5 – 10
System design	5 – 10
Presentation	7 – 8
Total	30 – 50

As a result of the project-based collaborative learning, the average student final grade increased 1.4 times as compared to the traditional approach and reached 4.3 on the 5-based assessment scale. The students interested in active approach obtained the highest scores whereas the weak students also improved their results to some extent.

Thanks to the team-based approach, the students not only maximised their practical learning experience to achieve the project goals, but also developed other important abilities in the following:

- *self-directed learning* – as a project may involve multidisciplinary knowledge which is not covered by the standard lecture material, students are driven to study and seek solutions which serve to enhance their understanding of the theoretical material
- *project management* – students organise a task based on the talents of each group member, and each defines their own task and manages their progress against a specified timeline
- *product design* – students have more scope to develop the project so as to display their inventiveness

4.3.3 Resume

1. Development of communication skills is one of the main goals of engineering education, therefore collaborative learning emphasises cooperation and creating team learning and developing culture and enhances various scientific perspectives and methods of learning, research and development in operation and action.

2. Collaborative learning has become the necessary part of the project-based and problem-based approaches in Advanced Course of Power Electronics for which a specific team-based methodology has been developed.

3. The course project developed in conformity with an active learning concept includes two stages, namely the stage of individual creativity and that of collective work which cover the first and the last part of the project where an integration of the various modules and testing the overall functioning of the system is required.

4. Thanks to this approach, the students increased their practical experience and succeed in self-directed learning, project management, and product design.

4.4 Summary of Chapter 4

In this chapter, three active learning methods developed for the master's study level are described.

First, the concept of e-laboratory and the set of computer-based laboratory works in the Advanced Course of Power Electronics have been offered. The e-laboratory promises the students to acquire the methods, skills, and experience related to the real power electronic equipment in a manner that is very close to the way they are being used in industry, helping the teachers to interact with the students and the specialists working in industry and utilising their practical experience and knowledge to improve the applicability and quality of the course.

Second, a composition of the problem-based and project-based learning approaches implemented in the coursework arrangement illustrates the effectiveness of these methods an important result of which is that the students acquire knowledge and skills to design more complex and sophisticated electronic systems, learning effectively the problem statement and understanding, task solution under the practical headings, as well as the result presentations.

The necessary part of the project-based and problem-based approaches in the Advanced Course of Power Electronics relates to the collaborative learning in which a specific team-based methodology has been developed. Herewith, the course project developed in conformity with an active learning concept includes two stages, namely the stage of individual creativity and that of collective work which cover the first and the last part of the project where an integration of the various modules and testing the overall functioning of the system is required. As a result, the students increase their practical experience and succeed in self-directed learning, project management, and product design.

CHAPTER 5. DEVELOPMENT OF LCMS AND PROSPECTS OF THE FUTURE RESEARCH

5.1 Web-Based LCMS to Study Electronics and Power Electronics

5.1.1 Introduction to LCMS

The convenient integrated university LMS described in Chapter 1 is the reporting system that generally does not include tools to create new contents or to deliver small packets of learning like the personal educational paths or original learning products. Therefore, other Internet technologies are potentially playing a key role in the context of learning and knowledge transfer [0813]. These tools include homepages, blogs, wikis, instant messengers, social bookmarks, podcasts, vodcasts, etc.

In contrast to an LMS, a *learning content management system* (LCMS) represents the web-based system to create, store, assemble, and/or deliver learning content on a friendly, reliable and secure way. As the LMS cannot roll down to achieve the necessary level of details, the LCMS requirements are as follows:

- they must impart the main knowledge of the field based on fundamental concepts
- they should involve techniques to apply this basic knowledge into the solution of the current and emerging problems
- they should be suitable for searching effective educational ways along with the changing learning situations

Contrary to an LMS working within an organisation, an LCMS manages learning content across the company training areas. It supplies the staff and students by the means to create and employ learning content without doubling of efforts. In the remote hosting approach, an LCMS may host the content in a central repository and allow numerous LMSs to access it.

Primary business problems that an LCMS solves are:

- centralised management of learning content for efficient searching and retrieval
- productivity gains around rapid and condensed development timelines
- outcomes regarding the assembly, maintenance and publishing, branding and delivery of learning content

LCMS solutions are suited to create original learning strategies, supporting gathering and organising content, leveraging content for many purposes, and operation for critical purposes. LCMS technology can either be used in tandem with

an LMS, or as a standalone application for learning initiatives that require fast development and distribution of learning content.

Advanced LCMSs comply with the following requirements:

- typical content management abilities such as electronic filing and file management
- compatibility and the ability to work with an LMS and other LCMSs
- content reusability
- rapid content creation, distribution, integration and authorising tools
- support of the convenient toolkits used in content creation such as Dreamweaver, Flash, Word, PowerPoint, etc.
- performance and extendibility of the environment
- multi-language support

Some of the best-known toolkits to create an LCMS are Moodle [WL17], Blackboard [WL03], .LRN [WL15] and ATutor [WL02]. These systems typically facilitate educational activities, providing a centralised environment to organise and disseminate information, support teacher-student communication, enable the document interchange, answer online questionnaires, etc. Presently, Moodle stands out with its features among other open-source LCMS toolboxes. This advanced system has the widest range of options with different access possibilities, modular structure, and powerful design tools.

Many engineering subjects require from their LCMS not just the delivery of contents, but also the performance of experiments, practical developments, and collaborative works among students. During the last years these activities have been supported in several ways by technology-based solutions developed outside the LCMS: simulators, remote labs, agent-based environments, games, immersive environments, etc. This problem has been identified as a LCMS drawback that needs to be solved. Up to date, some solutions have been proposed with limited success. For example, Moodle and Blackboard have capabilities to extend their own functionalities using the so-called “extensions” which often lack the means to monitor and control user work and cannot adjust the interaction of the users with the external tools.

Extensive research has been carried out in the last years to standardise learning content components and to make them usable in interoperable and maintainable content repositories of LCMS. The first steps herein present the so-called open educational resources (OER) – teaching, learning, and research digital tools available in the public domains that permit their free use, re-use or re-purposing by others [WL04]. Normally, they are accomplished from the learning objects the main goal of those is to be used for teaching and learning. To organise and help in the retrieval of learning objects, metadata labels have been defined and standardised. In this context, gathering the educational content is a matter of two factors: reusability, which implies to have the resource at the appropriate level of granularity, and availability, which tackles the idea of actual finding of the most appropriate

resources using a variety of techniques. Unfortunately, many authoring tools do not comply with these two factors up to now.

The LCMS like Moodle and WebCT provide educators with the new possibilities of knowledge delivery like file uploading, discussion boards, and chat room services to streamline and enhance the education processes. They provide a multi-user environment where the participants of an educational process can create, store, use, manage, and deliver digital learning content from a central object repository. Moreover, many LCMSs overcome multiple common learning deficiencies, like these:

- LCMSs are welcome with their build-in authoring tools by the companies which need learning on their own specialised procedures for those generic courses do not fill their bill.
- Traditional courses are bulky because they contain everything that everyone might need to know about a topic whereas many learners require only part of what that course has to offer, specifically, what they want to learn. To accomplish this, the courses must be broken down into reasonably sized learning objects and reassembled in the right-sized packages.
- LCMSs provide authoring tools to create new learning content. Most authoring packages use templates, storyboards, and/or forms to enable non-technical subject experts create new environment directly, bypassing intermediary programmers.
- The most sophisticated tools incorporate the ability to assemble and consolidate learning parts into learning paths or learning experiences that are personalised to a learner's profile, job description, assessment results, or requests. A learning path can obtain up-to-the-minute information because it is assembled “on the fly” rather than taken off the shelf.

5.1.2 Management of learning objects

Management of learning content is a related technology to learning management being its further development. In the multi-user LCMS environment the developers can maintain not only training modules but also all the individual pieces that make up learning content. LCMSs are proposed to operate at the “atomic” knowledge level being focused on the content design, control and publishing. LCMS applications allow users to create, import, search for and reuse the small units of digital learning content and assets, commonly referred to as *learning objects*.

An LCMS is a content-centric product unlike an LMS, which is a learner-centric system. In an LCMS the focus is on the authoring and management of reusable learning objects. Rather than developing entire courses for numerous audiences, LCMSs provide the ability for single course instances to be modified and republished for various audiences.

A learning object is a collection of content, practice, and assessment items that are combined based on a single learning objective. The objects stored in the centralised repositories commonly are available to course developers and content experts throughout an organisation for potential repurpose and reuse, thus allowing for the rapid assembly of customised educational needs. Learning objects carry many names, including content objects, chunks, educational objects, information objects, intelligent objects, knowledge bits, knowledge objects, learning components, media objects, reusable curriculum components, nuggets, reusable information objects, reusable objects, and testable units of cognition, training components, and units of learning. Learning objects which consist of the small “granules” of learning maintained in the frame of databases called repositories.

These assets may include media files developed in other authoring tools, assessment items, simulations, text, graphics or any other object that makes up the content within the course being created. They typically have a number of other components, which range from descriptive data to information about rights and educational level. All learning objects have the following key characteristics:

- being a new way of thinking rather than the traditional content which comes in a several hour chunk, learning objects are much smaller units, typically ranging from 2 to 15 minutes
- being a self-contained unit, each learning object can be taken independently
- being a reusable cell, a learning object may be involved in many contexts for different purposes
- being an aggregated unit, learning objects can be grouped into larger collections of content, including traditional course structures
- being tagged with metadata, every learning object has descriptive information, allowing it to be easily found by a search

Contemporary LCMSs provide tools for authoring and reusing or re-purposing their objects as well as the virtual spaces for student interaction (such as discussion forums, live chat rooms, and web-conferences). Due to this conformity issue, an acronym CLCIMS (Computer Learning Content Information Management System) is also widely used to create a uniform phonetic way of referencing any learning system software based on advanced learning technology methodology.

Many studies, for example [WL14], [0102], [0202], [0304], [0802], indicate that with an appropriate application of the LCMS technology and matching to a complete instructional plan for design and use of learning objects, such significant efficiencies can and will be achieved:

- ability to make instantaneous changes to the critical learning content
- rapid and productive content development
- harmonious collaboration among subject matter experts and course designers

- suitability to create numerous derivative versions of content applicable to different audiences from senior management to line-level workers
- finding and reusing the learning content “just-in-time” and “just enough”
- making content available through a wide array of outcomes, such as structured e-learning courses, DVD-ROMs, tutorial aids, print-based handouts for use in classroom settings, etc.

5.1.3 Development of a LCMS

The first step to reorganise the university LMS was taken by the author in 2009. In contrast to the then-existing structure, an idea to orient the LMS on the particular customers’ requests was proposed in [Z03]. To this aim, all the LMS users were divided into some categories that differed in the customer goals (Figure 5.1, a).

The goals of the educational staff are as follows:

- to prepare learning contents
- to arrange syllabi and instruction plans
- to provide initiate study activities
- to arrange feedback with the students

The goals of administration are as follows:

- to arrange the curricula
- to manage the timetables
- to manage student and teacher mobility
- to arrange corresponding educational processes

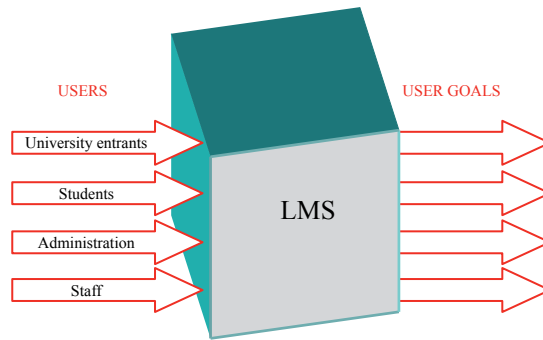
The goals of the students are as follows:

- to find the discipline and study relations
- to understand the full educational system
- to plan their study activity
- to monitor their own performance
- to be motivated for self-regulation
- to retrieve their learning profiles

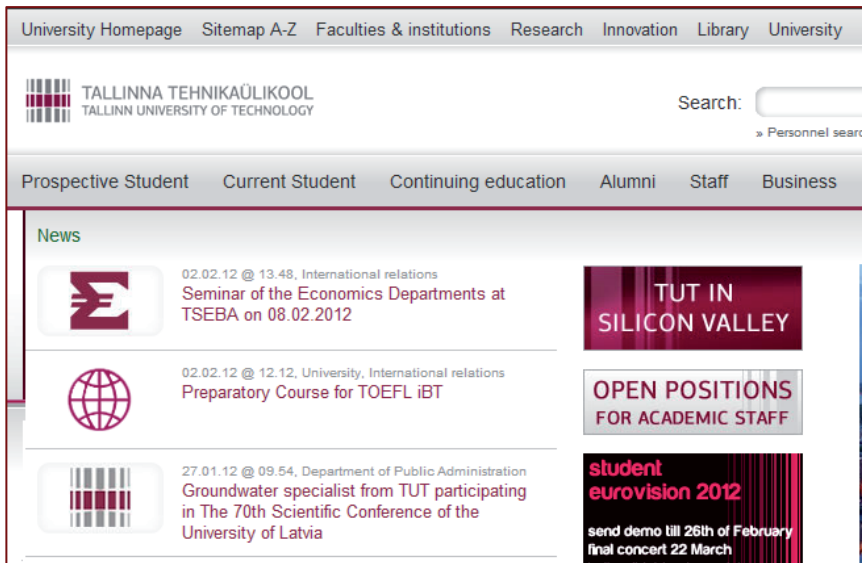
The goals of the university entrants are as follows:

- to find the future learning and curriculum details
- to study learning outcomes
- to understand the graduate work places and jobs
- to evaluate future positions, salary, grants, professional improvements, etc.

Later, this site structure was accepted and implemented in the actual TUT site [WL28] (Fig. 5.1, b). Next, an integration of the university LMS with the department LCMS was arranged.



a.

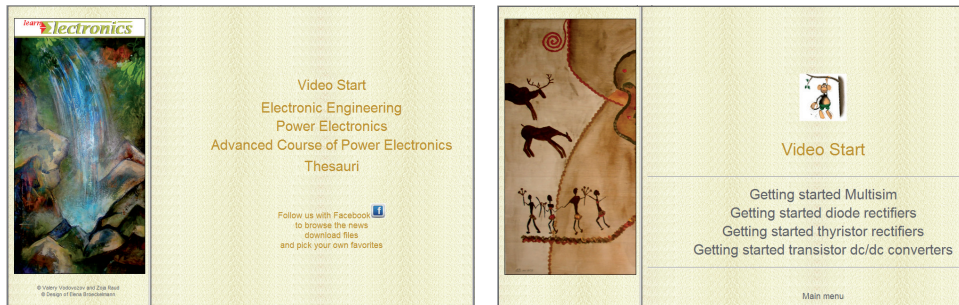


b.

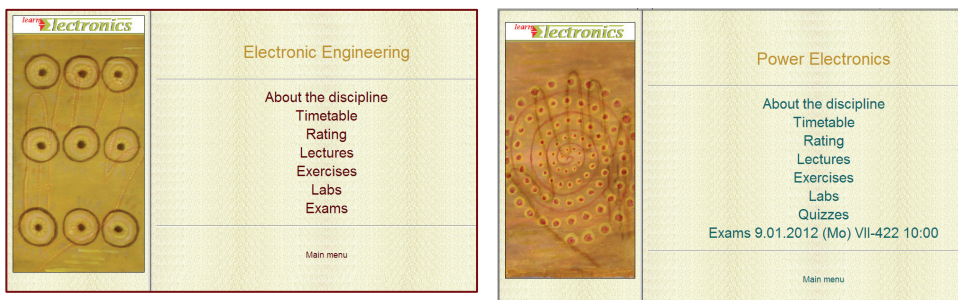
Figure 5.1. An idea (a) and current homepage (b) of the University site

In the new structure [Z21], [Z24], the LCMS became the sub-system of the university LMS. It was developed using an object-oriented approach to support the disciplines of Electronics, Power Electronics, and Advanced Course of Power Electronics. The tasks and services, such as giving out assignments electronically, online grading, and class note repositories are available through the Web. This system serves for providing additional channels for students to network and learn electronically. Furthermore, it can be used to extend and reach out to learners who might not otherwise have a chance to be actively involved in the regular learning process. This tool can be used to reach out to the “long tail” of learners, e.g. students with difficulty participating within a physical classroom, such as a part-time job, disabled, or a long commute [9001].

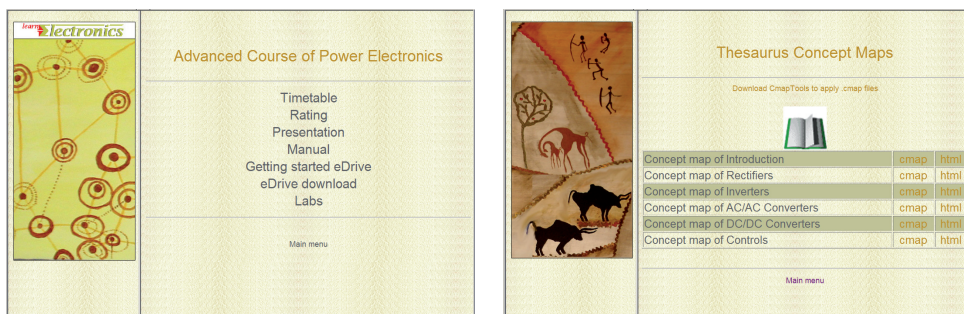
The core learning objects of the LCMS are stored in the repository of Estonian National e-Learning Portal [WL06]. The system involves the Web-textbooks on Electronics and Power Electronics, hypertext tutorial aids of exercises and laboratory practices, videos helping to start laboratory works and exercises, current assessment sheets, the lists of examination problems, and some other documents.



a .b
Figure 5.2. Homepage of LCMS and page “Video Start”



a. b.
Figure 5.3. Web pages of Electronic Engineering and Power Electronics



a. b.
Figure 5.4 Web pages of the Advanced Course of Power Electronics and Thesauri

The main windows of the LCMS cited in the Internet are shown in Figures 5.2, 5.3 and 5.4 [ZL01], [ZL02]. The system involves the Web-textbooks on Electronics [WL29], Power Electronics [WL30], and the Advanced Course of Power

Electronics [0824], hypertext tutorial aids of exercises and laboratory practices, video for starting exercises and laboratory works, assessment diagrams, the lists of examination problems, thesauri, and some other documents.

5.1.4 Resume

1. LCMSs facilitate educational activities, providing a centralised environment to organise and disseminate information, support teacher-student communication, and enable the document interchange, thus representing the web-based systems to create, store, assemble, and/or deliver learning content on a friendly, reliable and secure way.

2. The basic unit of an LCMS is a learning object which collects the content, practice, and assessment items that are combined based on a single learning objective. The objects stored in the centralised repositories commonly are available to course developers and content experts throughout an organization for potential repurpose and reuse, thus allowing for the rapid assembly of customised educational needs.

3. The developed LCMS effectively utilises methodical resources of Electronics, Power Electronics, and the Advanced Course of Power Electronics, particularly curricula, syllabi, schedules, studies, etc. At the same time, it enhances the learning process and students' activity being the stimulus in sharing students' and teachers' knowledge and experience.

4. The core learning objects of the developed LCMS stored in the repository of Estonian National e-Learning Portal contain the Web-textbooks on Electronics and Power Electronics, hypertext tutorial aids of exercises and laboratory practices, videos helping to start laboratory works and exercises, current assessment sheets, the lists of examination problems, and some other documents.

5.2 Management of Learning Content through Social Networking

5.2.1 Requirements for social networking

Regardless of the creation of such emerging e-learning tool like the LCMS, the Web is not yet transformed into a fully interactive space. The control of learning content needs in further decentralisation in order to allow everyone to collaborate, create, publish, subscribe, and share information. Obviously, new interventions are required to enhance network activity.

To help students to acquire the full cognitive development, lectures, labs, and exercises require more integrating of the teaching staff with particular learning styles. As [0820] claims, a learning style presents a distinctive manner of acquiring knowledge, skills, or attitudes through study while learning preference is favouring of one particular mode of teaching over another. Some students tend to focus on facts, data and algorithms; others feel more comfortable with theories and

mathematical models. Some conceive more from visual information whereas others get more from spoken and written forms. Some prefer interactive learning; others learn well individually. Existing studies show that matching learning styles with teaching methods improves academic achievements.

Contemporary learning occurs not only within the traditional classroom, but students as well as educators also often reach out to the abundance of information and knowledge outside the university [1107]. An important peculiarity of the breed of 21st century learners is that the teachers today have to deal with the popularly known “digital natives” or “net-gen” who are completely “wired” to the world of computers, television, mobile phones, and social networks [1108] [0908]. They are well aware of the Web usage in education and familiar with the Web-based e-learning tools to high extent. Many students are ready to experience new technologies in their study routines and are willing to collaborate using various communication modes. While social networks such as Facebook and Twitter have opened new possibilities for human interaction, these applications have barely begun to tap the wellspring of potential for collaborative learning with social media [1106]. Users of social sites can share personal information through their profile, connect with other users, upload, tag and share content that they have created, link others to a variety of web-accessible content, initiate or join sub-sets of user groups based on common interests or pursuits. The social networks have strong potential to enable instructors to build and maintain connections with and among the students and to create an informal learning environment by having students collaborate and learn from each other [0808]. Particularly, it is shown in [1008] [1011] that current utilisation rate of Facebook is far more than that of other online community platforms.

5.2.2 Development of social networking

Three associated aspects represent the problems of the introduction of social networking to education:

- the role of the tutor in electronic material delivery and explanation through social networks
- the place of learners in these processes
- the influence of the new communication systems on the adoption of learning content

Each of these aspects plays in augmenting learner activity and interaction, consequently incrementing the success of an educational system.

To enlarge the area of active learning, to increase integrating with individual learning styles, and to provide the participants with new possibilities, a link to follow the courses with Facebook was added to the LCMS in 2011 [ZL07], [Z27], [Z29]. The improved e-learning system prepared in the frame of the social medium involves the following components:

- personal profiles of participants
- posts by instructors which include mainly class announcements, homework inquiries, and coming quiz contents
- weekly assignment posts with current rating
- instructors' class introduction
- example videos and pictures
- comments from both instructors, students, and teacher's assistants
- tags from photo and video sections
- top bugs of passed quizzes, laboratory reports, and exercises
- private communications between instructors and students

Figure 5.5 shows the chronological timeline of learners' activities in the Facebook page. The first boom of activity occurred in the first academic weeks which were the busiest in terms of class assignments, as well as starting to get acquainted with the discipline which involved the first conversations and comments between participants. Next surges forestall the weekly lectures when the coming quiz problems are published. The splashes following the lectures indicate the students' interest in the quiz results and their discussions.

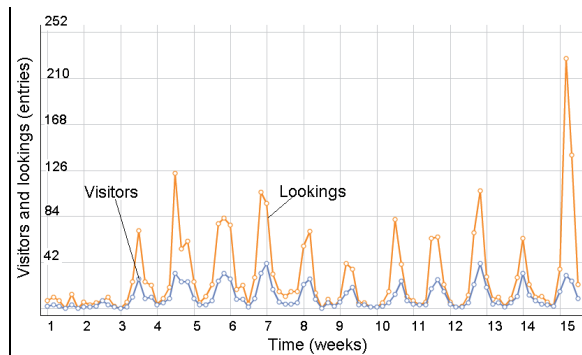


Figure 5.5. Timeline of learners' activity

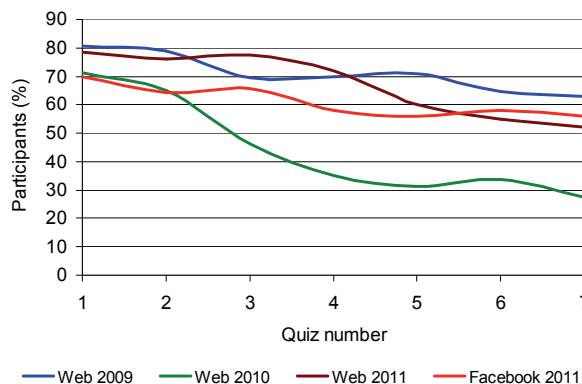


Figure 5.6. Participation in active learning

Figure 5.6 displays the percentage trends of the students' number who participated in active learning. Participation is reduced gradually because mostly the students whose score is not enough for self-examination cancel quiz attendance.

5.2.3 Analysis of social networking

An analysis of the students' participation in social networking represents the particular interest. It shows that, while the usual Web-based LCMS was used in 2009, 2010 in Electronics and Power Electronics and 2011 in Electronics, some groups of students failed their participation in active learning during the academic semester, and only 65 to 28 % finished successfully. The experience of the social networking in 2011 in Power Electronics increased the participation level and, accordingly, the final examination grades. The students who earlier succeeded in active learning now continue their activity. At the same time, some students who failed in the previous courses but feel strong in social networking start active participation in the new environment. Therefore, as was predicted in [0907], Facebook allowed the new groups of individuals to use their public profile for sharing a connection with other users in terms of learning. Moreover, the personnel has acquired enhanced ways to supply students of different learning styles with appropriate teaching materials, like films, pictures, formulae, and other tutorial aids.

In Figure 5.7, the average traces of quiz scoring are given. While the usual Web-based LCMS was used in 2009, and 2010 in Electronics and Power Electronics, no scoring growth was found. Moreover, there was a slump in the average rating because the students who felt that self-examining was impossible cancelled their participation in quizzing. The result of the social networking in 2011 shows the permanent growth of the students' current rating. Here, the participants could discuss the assessment results, requesting the staff and the colleagues about the problems and the methods of their solving.

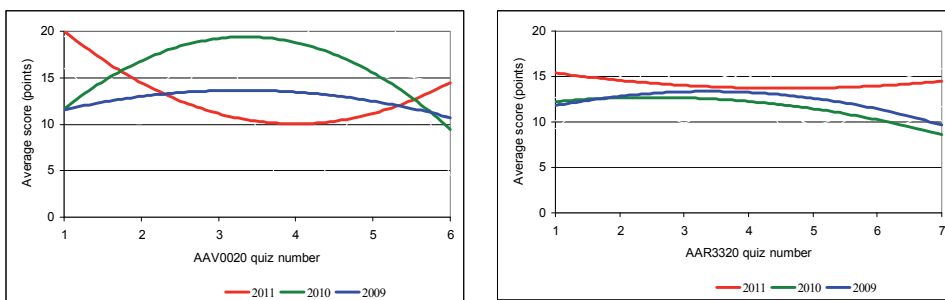


Figure 5.7 Average quiz scores

Those students whose current rating exceeds three were graded in the discipline without taking exams. In Figure 5.8, the percentage of the students who succeeded in self-assessment is shown. The highest level of the self-examined students in 2011 confirms the positive role of social networking in active learning.

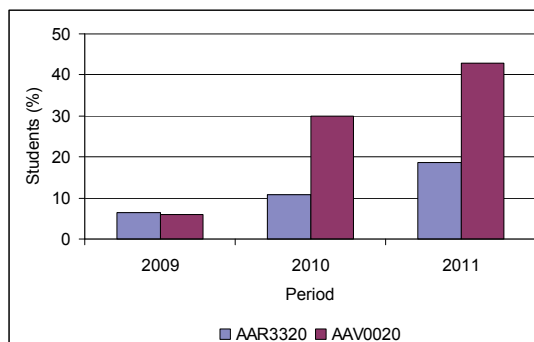


Figure 5.8. Percentage of the students who succeeded in self-assessment

In this way, the social network provides learners with the outside-classroom extension of interaction and learning with peers has a significant influence on learning in an informal manner. Thus, the new Internet tool adopted the features of social network to attract learners making the learning process more effective and successful, providing more opportunities in knowledge acquisition for learning through the context provided by an interactive content [WL13]. Also, this means that, though an intervention itself does not feed motivation, but it certainly can activate some groups of users [0203].

According to Tables 5.1 to 5.4 and Figure 5.9, an increased evaluation of the new learning by the students was confirmed by official university statistics [WL27].

Table 5.1. Active learning with social networking evaluation by students in spring 2011

Question	AAR3320	Department	Faculty	University
Compliance of the course with the goals of my programme	4.88	4.52	4.3	4.12
Achievability of learning outcomes (results) of the course	4.25	4.23	4.11	4.07
Logical organisation and integrity of the course	4.75	4.16	3.98	4.04
Interconnectivity between the course and other courses	4.5	4.16	4.04	3.83
Provision of study materials	4.5	3.93	3.86	3.96
Compliance of credit points for the course with the capacity of work required for accomplishment of the course (1 CP=26 hours of student work)	4.38	4.1	4.09	4.14
Average 2011	4.54	4.18	4.06	4.03

Table 5.2. Active learning evaluation by students in spring 2010

Question	AA3320	Department	Faculty	University
Compliance of the course with the goals of my programme	4.42	4.01	3.97	4.07
Achievability of learning outcomes (results) of the course	3.67	3.67	3.73	4
Logical organisation and integrity of the course	4.17	3.33	3.63	3.97
Interconnectivity between the course and other courses	4	3.67	3.66	3.76
Provision of study materials	3.83	3.48	3.53	3.91
Compliance of credit points for the course with the capacity of work required for accomplishment of the course (1 CP=26 hours of student work)	3.5	3.8	3.88	4.06
Average 2010	3.93	3.66	3.73	3.96

Table 5.3. Active learning with social networking evaluation by students in autumn 2011

Question	AAV0020	Department	Faculty	University
Compliance of the course with the goals of my programme	5	4.34	4.26	4.1
Achievability of learning outcomes (results) of the course	4.5	3.8	4.23	4.05
Logical organisation and integrity of the course	4.75	3.44	4.07	4
Interconnectivity between the course and other courses	4.5	3.75	3.98	3.83
Provision of study materials	4.5	3.61	3.92	3.94
Compliance of credit points for the course with the capacity of work required for accomplishment of the course (1 CP=26 hours of student work)	4.75	4	4.24	4.14
Average 2011	4.67	3.82	4.12	4.01

5.2.4 Resume

1. To help students to acquire the full cognitive development, lectures, labs, and exercises require more integrating of the teaching staff with students taking into account that contemporary learning occurs not only within the traditional classroom, but students as well as educators also often reach out to the abundance of information and knowledge outside the university.

Table 5.4. Active learning evaluation by students in autumn 2010

Question	AAV0020	Department	Faculty	University
Compliance of the course with the goals of my programme	5	4.34	4.44	4.11
Achievability of learning outcomes (results) of the course	3.75	3.75	4.03	4.06
Logical organisation and integrity of the course	4.25	3.71	4	4.04
Interconnectivity between the course and other courses	4.25	3.87	4.02	3.84
Provision of study materials	4	3.82	3.9	4
Compliance of credit points for the course with the capacity of work required for accomplishment of the course (1 CP=26 hours of student work)	4	3.97	4.05	4.15
Average 2010	4.21	3.91	4.07	4.03

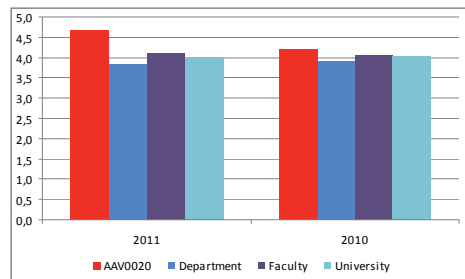
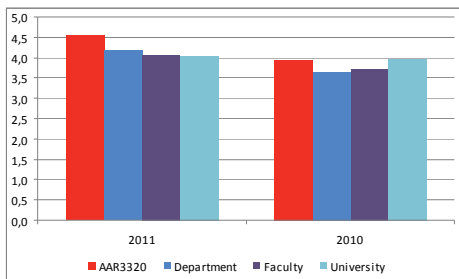


Figure 5.9. Students' evaluation of the courses of Electronics (AAR3320) and Power Electronics (AAV0020)

2. To enlarge the area of active learning, to increase integrating with individual learning styles, and to provide the participants with new possibilities, a link to follow the courses with Facebook was added to the developed LCMS.

3. The social networking increased the participation level and, accordingly, the learners' current rating and the final examination grades of the students, specifically those who failed in the previous courses but feel strong in social networking.

4. An increased evaluation of the new learning by the students was confirmed by official university statistics, therefore the new Internet tool adopted the features of social network, making the learning process more effective and successful, providing more opportunities in knowledge acquisition for learning through the context provided by an interactive content.

5.3 Prospects of Learning Management Based on Flexible Curricula

5.3.1 Innovative training set-ups and practices in industrial companies

In many sectors, specialists are generally responsible for driving innovation and competition. Contemporary changes in the business sector, responses of enterprises to these changes, as well as available information and communication technologies pose a number of challenges to the engineering staff [0704], such as:

- continuous learning of new technologies and methods
- fast promotion of projects in the frame of time scarcity
- maintenance of manufacturing systems based on the online tools and resources
- active personal development and competency improvement

Companies require from their engineers an aptitude for collaborative work, team and task management, concept synthesis, and decision-making, thus stimulating progress in the learning environment, which gives all of these job-related skills.

Over the past few years, there has been increasing interest in effective lifelong learning technologies for engineering. To promote staff development, employees usually attend training courses, workshops, seminars, and conferences. With advancements in technology, organisations are engaging to employ different educational media to enhance staff skills and knowledge. In addition, training on the job and situation-based learning are increasingly considered in the modern fast changing knowledge society. However, most research and surveys indicate that enterprises have a limited capacity and participation in continuous education and training. It is confirmed also by the author's own findings that companies are slow to implement new educational approaches and the staff does not benefit much from training because of their context of work, productivity and time.

To recognise the optimal learning pathways, the definition of the professional profiles has been offered in [0906]. Using such profiles, company representatives may choose between different courses and educational institutions to find the most appropriate for their profile specifics and targets. In [0703], an overview of educational strategies used in enterprises is also given and a number of attempts to increase their effectiveness are listed. With that end in view, learning in industry is divided into formal training and vocational training. Formal approach is classified as training arranged and packaged to cover a given subject, with clearly defined topics, eventually leading to the delivery of a certification whereas vocational approach relates to training, the costs of which are supported by the company and the topics of which are related to individual jobs. Moreover, it is presented in [0603] that apart from the normal working environment, staff training also occurs in social events and in everyday activities. This means that work activity is carried out in various social settings where employees collaborate and interact on specific subjects. Therefore,

enterprises have to integrate learning from economic, human and social perspectives.

Following an analysis of the promoted innovative set-ups and practices in world industrial companies, this section proposes a novel approach to curricula scheduling. The aim is to facilitate and improve the quality and efficiency of in-service training, on-the-job training, and undergoing training provided in a workplace environment. An appropriate educational model is grounded, enabling development of optimal training trajectories in the framework of the curricula organisation, particularly in the field of power electronics. The focus is on the re-evaluation of the syllabi design along with the strengthening of e-learning role using the conceptual approach. Effective instruments are given to find an institution capable of providing training in such environments.

5.3.2 Flexible curriculum

To enlarge the conception of the ET given in Chapter 2 across the full curriculum, assume a thesaurus of a particular speciality comprising M entries that represents the sum of entries of K disciplines of the speciality, $M = \sum m$. Let DIS_k be a component of CON_i which corresponds to the k -th discipline of a curriculum as follows:

$$CON_i = \{i, DIS_k, Term_i, D_i(T_{i1} \dots T_{ip})\}, \quad (5.1)$$

where $k = 1 \dots J$, $T_i \neq Term_i$, $p < M$. As accepted before, i is a concept index, $Term$ is the term which titles the concept, and D is the concept definition (Table 5.5).

Table 5.5. Matrix of the curriculum thesaurus

i	DIS	$Term$	T_1	T_2	...	T_j	T_{j+1}	...	T_{m-1}	T_m
1	DIS_1	$Term_1$	$w_{1,1}$	$w_{1,2}$	...	$w_{1,j}$	$w_{1,j+1}$	...	$w_{1,m-1}$	$w_{1,m}$
2		$Term_2$	$w_{2,1}$	$w_{2,2}$	...	$w_{2,j}$	$w_{2,j+1}$	...	$w_{2,m-1}$	$w_{2,m}$
:		$Term_3$	$w_{3,1}$	$w_{3,2}$	...	$w_{3,j}$	$w_{3,j+1}$	...	$w_{3,m-1}$	$w_{3,m}$
i	DIS_k	:	:	:	:	:	:	:	:	:
$i+1$		$Term_i$	$w_{i,1}$	$w_{i,2}$	...	$w_{i,j}$	$w_{i,j+1}$	...	$w_{i,m-1}$	$w_{i,m}$
:		$Term_{i+1}$	$w_{i+1,1}$	$w_{i+1,2}$	...	$w_{i+1,j}$	$w_{i+1,j+1}$	...	$w_{i+1,m-1}$	$w_{i+1,m}$
$m-1$	DIS_K	:	:	:	:	:	:	:	:	:
m		$Term_m$	$w_{m,1}$	$w_{m,2}$	...	$w_{m,j}$	$w_{m,j+1}$	...	$w_{m,m-1}$	$w_{m,m}$

Call the number of concepts M a student should acquire within the full learning period as the *length of an educational trajectory*.

Since the thesaurus is ranged, the neighbour concepts may be involved into the groups outlined in the column DIS of Table 1 and in Figure 5.10. To associate these groups with the disciplines of a curriculum, assume the following.

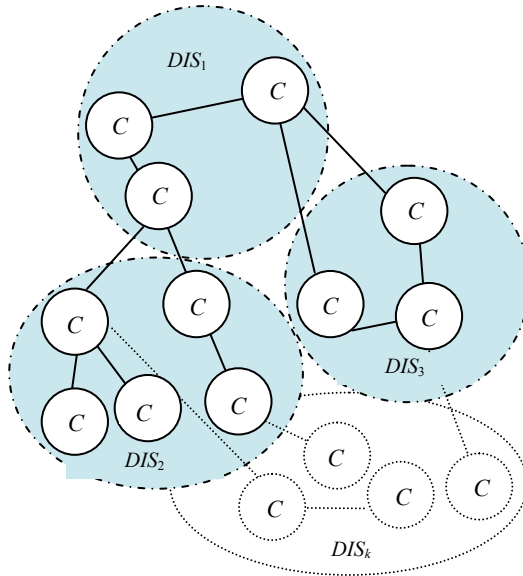


Figure 5.10. Concept aggregating with disciplines

The study volume in the curricula is recorded according to the European Credit Transfer and Accounting System (ECTS). The ECP conforms to 26 hours of study. The overall volume for an academic year amounts to 1560 hours or 60 ECP. The number of credit points ECP_{total} measured in hours for the bachelor's, master's, or doctoral programme is given by an appropriate educational standard [0602]. Particularly, the degree programme volumes in the field of Electrical Drives and Power Electronics are as follows:

- bachelor's programme – 180 ECP, nominal study period of 3 years
- master's programme – 120 ECP, nominal study period of 2 years
- doctoral programme – 240 ECP, nominal study period of 4 years

The number of hours devoted to each discipline is restricted by their minimum and maximum values, typically $H_{min} = 26$ and $H_{max} = 156$. Consequently, the number of credit points covered by a discipline is restricted by ECP_{min} and ECP_{max} . Therefore, the total number of disciplines in a curriculum is

$$K \in \left[\frac{ECP_{total}}{ECP_{max}}, \frac{ECP_{total}}{ECP_{min}} \right].$$

The maximum K is usually restricted by the permissible number of assessments A in a semester and by the number of semesters S in a study programme:

$$K \leq A \cdot S.$$

The average number of concepts introduced in a discipline depends on the thesaurus capacity M as follows:

$$m = \frac{M}{K}.$$

For instance, let the capacity of the thesaurus $M = 20000$ concepts [WL11], $ECP_{total} = 180$, $H = 52$ hours, $A = 7$, $S = 6$, $ECP_{max} = 6$, and $ECP_{min} = 1$. Then $K \in [30, 180]$ and $K_{max} \leq 42$. Assume $K = 40$. Therefore, the average number of concepts m introduced in a discipline is about 500. Particularly, at TUT about 800 concepts are introduced in Electronics, but only 200 in Power Electronics [Z18], [Z22], [Z25].

From now on, a curriculum may be represented by a double-level model figuratively shown in Figure 5.11 which includes

- top curriculum level as an ordered system of disciplines $DIS_1 \dots DIS_K$, $K < M$, which shows an educational trajectory of a learner
- concept matrix, which serves as a source for the top level

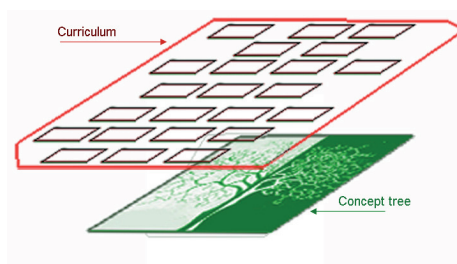


Figure 5.11. Double-level model of the curriculum

From this viewpoint, the curriculum arrangement poses the process whereby the components are interpreted through the learning experiences [0802].

Let i_{DIS} be a given starting instant where a discipline DIS_k begins. In the simplest case, when $p = 0$ (no predetermined concepts), $i = i_{DIS}$, which means that all such concepts CON_i may be introduced starting from the first study of DIS_j . The same concerns the defined concepts described by the components of the earlier passed disciplines. For instance, if $i_{DIS1} < i_{DIS2} < i_{DIS}$ and CON_i is defined by the predetermined concepts of i_{DIS1} or i_{DIS2} , then $i \geq i_{DIS}$.

To support the basic concepts of an application area and to reflect the challenges being an instrument for solving the practical problems of companies, a thesaurus should possess sufficient redundancy. In fact, different professional branches of knowledge require the sets of defined concepts, thus an excess capacity of concepts and disciplines is the normal feature of any thesaurus. For example, the known

branches of Power Electronics are as follows: Industrial Electronics, On-Board Electronics, Aircraft Electronics, Automotive Electronics, Military Electronics, etc.

As the number of concepts M a student should acquire within the learning period is less than the total number of the professional concepts M_{Σ} , the personal educational trajectories may differ depending upon the staff goals and the future degree that a learner approaches. To enhance the engineers' knowledge level for different enterprises, specific educational trajectories are needed, therefore different groups of concepts and particular disciplines of the full thesaurus may be selected.

Hence, the offered system of the consolidated disciplines aggregated into a curriculum represents a suitable tool to generate the required educational trajectories. Being connected by means of concepts, the disciplines successfully support the total plan for learning. In Figure 5.10, the solid nodes and branches outline the appropriate educational trajectory whereas the remaining concepts deleted from the total thesaurus are given by the dotted lines.

In addition to the concepts and disciplines, a curriculum may include everything that promotes the learners' intellectual, personal, social and physical preferences [0910]. It may also involve the studies, extracurricular activities, approaches to teaching, learning and assessment systems, the quality of relationships within a department, and the values embodied in the way the department operates.

Unlike the traditional environment, the proposed model of learning has an exclusively dynamic nature; therefore, it may be called as a *flexible curriculum*. Any time when the professional level is raised, the curriculum may be changed simultaneously along with its background conceptual matrix. Thus, new disciplines are introduced, the contents of the corresponding disciplines refreshed, and the borders between the disciplines shifted fluently. This promotes designing the teaching modules in highly interdisciplinary areas and in the areas with specific needs.

5.3.3 Defining of the optimal educational trajectories

Design and control of the personal educational trajectory is a new problem suitable for solution by the developed approach. Consideration of learning paths concerns the sequence of learning objects consumed by the students, which defines a trajectory of navigation to plan the student activities. Finding the correct individual learning paths leads to achieving a flexible platform for all the participants of an educational process. Such a self-monitoring system follows the progression of individual learning. It will allow students to have greater flexibility in learning, thus reducing many constraints to progress. By comparing the optimal trajectory with the actual one, the learning quality and the student knowledge level are evaluated to suggest the corrective actions. All this can be considered as a control loop with a fast feedback the response of which to deviations provides the system stability.

Definition of the optimal educational trajectories helps the following:

- to evaluate the complexity of the particular disciplines and the full specialty curriculum
- to optimise the order of the disciplines in the curriculum
- to design curricula for an additional education and for the second specialty

The common information problem may be formulated as follows. The previously studied discipline (specialty) is based on a system of concepts A . The new discipline (specialty) is based on a system of concepts B , some of which may be the concepts of A . Find an educational trajectory between the new and previously studied disciplines (specialities).

If among the concepts of B there is at least one defined through the concept of A , the two systems can be described together by a graph T and the solution of the problem is reduced to finding a path between these concepts in T using the known algorithms of the theory of information, for example, Dijkstra's algorithm [8201]. Thus, the challenge is to find the terms of B that correspond to the concepts of A . If there are no concepts of A among the concepts in B , but there is a concept from some other discipline K , which in turn has a concept from A , then K acts as an intermediary discipline. In this case we should find a path between the appropriate concepts in K using the same algorithm again.

An example is given below. Assume the previously studied discipline called Power Electronic Converters (PEC) includes some concepts like the following:

1. **power electronic converter (PEC)** – *electronic converter* that converts *energy* within a *power electronic system*
2. **dc/dc converter** – PEC converting *dc* to *dc* of another level
3. **load** – object connected to the **PEC** output
4. **supply** – *power* line feeding the **PEC**
5. **switching dc converter** – **dc/dc converter** using a *switching* principle of operation
6. **boosting** – production of a *load voltage* above the *supply voltage*
7. **booster** – PEC with **boosting** possibilities
8. **buck converter** – **switching dc converter** which output *voltage* is below the input *voltage*
9. **boost converter** – **booster**
10. **buck-boost converter** – **buck converter** combined with a **boost converter**

Here, the concept terms are given by a blue type and an italic font is used for the terms coming from prior disciplines, such as Electronics and Electrical Engineering. The defined concept terms occupy the left side of each entry whereas the definition functions of their parents are to the right. In Figure 5.12 the graph of these concepts is shown to the right, where the dotted arrows mark the incoming terms.

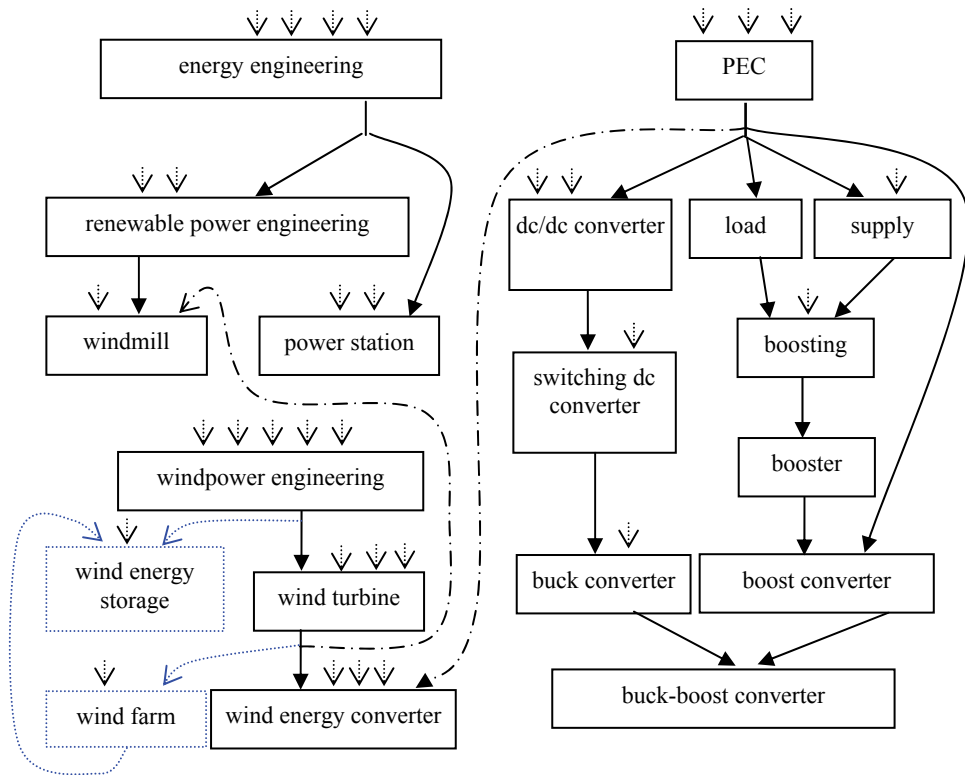


Figure 5.12. Semantic graph of a fragment of an ET

Let the new discipline Energy Engineering includes the concepts given below:

1. **energy engineering** – field of engineering dealing with energy management, plant engineering, and environmental compliance
2. **power station** – **energy engineering** system for the generation of *electric power*
3. **renewable power engineering** – field of **energy engineering** dealing with *energy* which comes from the renewable *natural resources*
4. **windmill** – *machine* used in **renewable power engineering** to apply *mechanical energy* directly from a *wind turbine*

An intermediary discipline Windpower Engineering includes the following concepts:

1. **windpower engineering** – discipline focused on the *design engineering, maintenance, installation, and projects* related to the *wind power*.
2. **wind turbine** – *rotary device* used in **windpower engineering** to extracts *energy* from the *wind*

3. **wind energy converter** – *machine* to convert *mechanical energy* of **wind turbine** to *electricity* using *PEC*
4. **wind farm** – group of **wind turbines** in the same location used for production of *electric power*
5. **wind energy storage** – equipment used in windpower engineering to store *electricity* of wind farm

The graph fragments of Energy Engineering and Windpower Engineering are given in Figure 5.12 to the left. Clearly, there are no terms of *PEC* among the terms in Energy Engineering. At the same time, the concept *windmill* is defined by the term *wind turbine*, which participates the discipline Windpower Engineering and there is a concept *wind energy converter* defined by *PEC* in the discipline Windpower Engineering. Therefore, Windpower Engineering acts as an intermediary discipline, in which one should find a path for a *wind energy converter*. Thus, the length of the full educational trajectory is equal to the length of the new discipline Energy Engineering plus the length of the educational trajectory in the intermediary discipline Windpower Engineering for the concept of the *wind energy converter* that is $3+2=5$. The remaining concepts of a *wind farm* and the *wind energy storage* of this discipline are optional for study.

5.3.4 Resume

1. Many studies and surveys indicate that small- and medium-sized enterprises have a limited capacity and participation in continuous education and training; companies are slow to implement new educational approaches and the staff does not benefit much from training because of their context of work, productivity and time.

2. A novel model of the curriculum built on the educational thesaurus supports the overall set of concepts actual for definite enterprises and applies them to solve the practical problems, thus proposing a flexible and easily upgradeable educational system.

3. This tool is suitable for numerous educational trajectories to be developed for different groups of learners where the learning outcomes are described in concepts and terms that make institutions more responsive to the needs of the market and to reinforce the links between studies and employment needs.

4. An application example linking three disciplines across their conceptual basis confirms the effectiveness of the proposed methodology.

5.4 Summary of Chapter 5

This chapter is devoted to the use of the new Internet environment to support active learning. The findings resulting from the experience presented in this section provide interesting indications focused on the management of learning that combines different Internet technologies. Overall, this experience has realised positive learning outcomes both for students and instructors. For students, it

increases the learning level through informal communication, support for collaboration, and exchange on thoughts. Instructors have succeeded in gaining feedback from students and in producing an effective instructional technology for learners' stimulation.

Following the careful study of the learning outcomes and official university statistics, it can be concluded also that the learning content management system that combines Web services and social networking has a broad potential for the future by expanding teaching and learning beyond the classroom.

Next, the prospective educational technology suitable for planning optimal training trajectories is grounded. Effective instruments are given to build the most appropriate professional thesauri and to find an institution capable of providing training in the frame of such thesauri. Any time when the professional level is raised, the proposed curricula may be changed simultaneously along with their background conceptual matrix. Thus, new disciplines can be introduced, the contents of the corresponding disciplines refreshed, and the borders between the disciplines shifted fluently. This promotes designing the teaching modules in highly interdisciplinary areas and in the areas with specific needs.

CONCLUSIONS

In this thesis the research and development of the new active learning technology in the field of electronics and power electronics are presented. The most important results of the thesis are as follows:

1. The analysis of the promoted innovative setups and practices of educational systems that revealed the necessity to develop a new education technology based on the Bologna Declaration and on the approaches that move the responsibility of learning on learners by shifting from time-based to achievement-based education.

2. Most prospective novel educational solutions found in the study relate to the e-learning techniques, effective assessment methodology, and progressive learning management system which provide the development of reflective thinking, thus enabling staff and students to manage better the learning process and skills acquisition.

3. Launching the object model, the major learning objects were introduced in the thesis, such as concepts, disciplines, syllabi, and studies, an analysis of which revealed serious shortcomings of the traditional curricula including inappropriate grouping principle of the disciplines, poor intercommunication and repeating of the course contents, and the rigid structure of the curricula unsuitable for changes.

4. The survey of the students' learning preferences and expectations arranged by the author exposed that the majority of learners are seeking to acquire the purposeful and applied education using active learning techniques and effective training possibilities.

5. An analysis conducted in the thesis expanded the drawbacks of the conventional thesauri from the educational viewpoint and became the starting point for the development of a new tool, namely an educational thesaurus the design principles of which were proposed and grounded.

6. Following these principles, effective thesaurus filling and ranking procedures and algorithms were developed that prevent conceptual recursion and repetition, restrict the number of parents in the new concept definitions, promote concept redefining, and support finding the starting position at which concepts may be introduced into the thesaurus.

7. Suitability of the thesaurus for learning management was confirmed by cited examples and implementation results. It was shown that application of the educational thesaurus is important for the conceptual thinking and appreciation of the learning process, enabling the learners to overcome the barrier between the practical application and the theoretical knowledge, and promoting learning and ultimately students' progress and achievement.

8. As the traditional teaching has many drawbacks, to enhance student opportunities in knowledge and skill acquisition, an active learning technology was introduced at TUT into the courses of Electronics, Power Electronics, and the Advanced Course of Power Electronics. It covers the novel format of the courses with the primary role of exercises and labs, the content deployment upon the two layers, namely compulsory material and optional issues, and the significant volume of the optional resources that engage students in their learning.

9. As a part of active learning technology, the model-based approach to exercises was developed that makes the students responsible themselves for the circuit design and diagnosis, teaches them to become experts in the circuits and obtain a variety of experiences with most types of circuits. Five basic activities were proposed to promote active learning and to give constructive feedback between the students and instructors, namely off-site preparation, in-class pre-work talk, performance in a lesson, in-class summing-up discussion, and off-site reporting, each included mandatory and optional works.

10. The active approach offered to the laboratory practice stimulates strong students' efforts in their success in active learning. Thanks to the same five basic activities as in the exercise lessons, the suggested laboratory arrangement helps to develop such practical skills as the problem solution upon practical headings, effective calculations, experimentation performance, equipment selection, skill experience, and qualification acquisition.

11. The developed assessment methods in the active learning context introduced into Electronics, Power Electronics, and the Advanced Course of Power Electronics promote ultimately students' progress and achievement and have influence on what learners learn, how effectively they learn, and consequently on the quality of their learning. To motivate students' self-assessment, the specific self-assessment modules were prepared as the combination of homepages and Excel worksheets that include the rating tables accompanied by the evaluation rules.

12. The concept of an e-laboratory and the set of computer-based laboratory works in the Advanced Course of Power Electronics have been provided. They encourage the students to acquire the methods, skills, and experience related to the real power electronic equipment in a manner that is very close to the way they are being used in industry. This approach helps the teachers to interact with the students and the specialists working in industry and utilises their practical experience and knowledge to improve the applicability and quality of the course.

13. A composition of the problem-based and project-based learning approaches implemented in the coursework arrangement illustrates the effectiveness of these methods the important result of which is that the students' acquire knowledge and skills to design more complex and sophisticated electronic systems, learning effectively the problem statement and understanding, task solution under the practical headings, as well as the result presentations.

14. The necessary part of the project-based and problem-based approaches in the Advanced Course of Power Electronics relates to collaborative learning for which a specific team-based methodology has been developed. Herewith, the course project developed in conformity with an active learning concept includes two stages, namely the stage of individual creativity and that of collective work. As a result, the students increased their practical experience and succeeded in self-directed learning, project management, and product design.

15. The thesis provides interesting indications focused on the management of learning that combines different Internet technologies which realised positive effects for both the students and the instructors. For students, they increase the learning level through informal communication, support collaboration, and exchange of ideas. Instructors have succeeded in gaining feedback from students and in producing an effective instructional technology for learners' stimulation.

16. Following the careful study of the learning outcomes and official university statistics, it was concluded that the learning content management system that combines Web services and social networking has a broad potential for the future by expanding teaching and learning beyond the classroom.

17. A prospective educational technology suitable for planning optimal training trajectories was grounded. Herewith, effective instruments are given to build the most appropriate professional thesauri and to find an institution capable of providing training in such thesauri. Any time when the professional level is raised, the proposed curricula may be changed simultaneously along with their background conceptual matrix. Thus, new disciplines can be introduced, the contents of the corresponding disciplines refreshed, and the borders between the disciplines shifted fluently. This promotes designing the teaching modules in highly interdisciplinary areas and in the areas with specific needs.

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ABSTRACT

Zoja Raud

Research and Development of an Active Learning Technology for University-Level Education in the Field of Electronics and Power Electronics

Tallinn 2012

Tallinn University of Technology

This doctoral thesis concentrates on the methods and tools that attract learners and educators in making the educational process in the field of Electronics and Power Electronics maximally effective and successful. The study aims to provide the participants of the educational process with an effective environment, enhancing their opportunities in the knowledge acquisition and appreciation. The scientific contributions of the thesis include a learning/teaching technology built on a novel conception of educational thesaurus, new tools for the bachelor's and master's study that extend the sphere of the active learning technology upon the field of electronics and power electronics, and a learning content management system covering the field of electronics and power electronics. The practical value involves an increased skill area of the graduates, enlarged possibilities for students to acquire knowledge and skills and share them between themselves, enhanced descriptiveness and attractiveness of learning, effective instruments for information search, comparison and evaluation, suitable tools for onsite and off-site education, including staff consulting and peer-to-peer collaboration, and an easy self-assessment environment with fast feedback and learning correction. The thesis outcomes cover an enhancement of the students' skill in the field confirmed by the professional quizzes and examination grades, an increased evaluation of the new learning by the students confirmed by university statistics, and an enlarged learners' favour to the disciplines and to the speciality.

Keywords: electronics, power electronics, engineering education, active learning, learning management system, thesaurus

KOKKUVÕTE

Zoja Raud

Aktiivõppetehnoloogia uurimine ja väljatöötamine kõrghariduse õppekavale elektroonika ning jõuelektronika valdkonnas

Tallinn 2012

Tallinna Tehnikaülikool

Doktoritöö käsitleb meetodeid, mis teevad õppeprotsessi maksimaalselt efektiivseks ja edukaks nii üliõpilastele kui ka õppejõududele elektroonika ning jõuelektronika õppimisel. Uuringu eesmärk on suurendada üliõpilaste ja õppejõudude võimalusi teadmiste omandamisel, hinnata ja arendada soodsat õppekeskkonda, pakkumaks protsessis osalejatele uusi aktiivõppe meetodeid. Doktoritöö teaduslik panus koosneb õppimise/õpetamise tehnoloogiale põhinevast uuest õppetesauruse (Educational Thesaurus) kontseptsioonist, uudsetest bakalaureuse- ja magistriõppe meetodeist, mis hõlmavad aktiivõppe tehnoloogiat ja õppesisu haldussüsteemi (Learning Content Management System) elektroonika ning jõuelektronika valdkonnas. Töö praktiliseks väärtuseks üliõpilaste jaoks on võimaluste suurenemine professionaalsete teadmiste ja oskuste omandamisel ning nende jagamisel omavahel. See tõstab õppeprotsessi efektiivsust, tõhustab infootsingu tulemusi ja võimaldab kiiret tagasisidet kaasaegse e-õppe süsteemi ja enesehindamise keskkonna kaudu. Testimine, eksamitulemused ja ülikooli õppetöö hindamise statistika kinnitavad doktoritöö kasulikkust, mis väljendub üliõpilaste professionaalsete teadmiste suurenemises ja positiivses suhtumises oma erialasse ja õppeainetesse.

Märksõnad: elektroonika, jõuelektronika, inseneriharidus, aktiivõpe, õppeinfosüsteem, tesaurus.

Curriculum Vitae

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Tallinn Polytechnical Institute	1983	Dipl. Eng.
Tallinn 6 School	1977	Basic

4. Language competence/skills (fluent; average, basic skills)

Language	Level
Estonian	Fluent
Russian	Native
English	Fluent

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Period	Organisation	Position
2010-	Tallinn University of Technology	Teaching assistant
2005-2010	Tallinn University of Technology	Engineer, project manager
1983-2005	Tallinn University of Technology	Engineer

6. Scientific work

2011 – 2015 Project SF0140016s11 “New Converter Topologies and Control Methods for Electronic Power Distribution Networks”

2009 – 2012 Project ETF8020 “Research of Advanced Control and Diagnostics Systems for the High-Power IGBT Converters”

2008 – 2011 Project ETF7572 “High Power DC Voltage Converters with High Frequency Transformer Link”

2006 – 2007 Project EAS656F “Power converters for onboard equipment of electrical transport”

7. Defended thesis

“Electromagnetic Transport System” (Dipl. Eng, 1983, TPI)

8. Main areas of scientific work

Natural Sciences and Engineering, Electrical Engineering and Electronics (Educational Technologies in the Field of Electronics and Power Electronics)

9. Other research projects

2006-2008 Project IN631 “Development of the Training System for Electrical Engineers”

2005-2008 Project IN577 “Implementation the International Interdisciplinary Project-Based Learning in Electrical Drive, Electronics, Automation, and Mechatronics to Master Study Curriculum”

Elulookirjeldus

1. Isikuandmed

Ees- ja perekonnanimi Zoja Raud
 Sünniaeg ja –koht 30.03.1960, Tallinn
 Kodakondsus Eesti

2. Kontaktandmed

Address Majaka 6-25 Tallinn 11412
 Telefon +372 55665916, +372 6203694
 E-posti aadress zoja.raud@ttu.ee

3. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	Lõpetamise aeg	Haridus (eriala/kraad)
Majanduse ja Juhtimise Instituut	2002	Sotsiaaltöõjuht
Leningradi Riiklik Ülikool	2002	Psühholoog
Tallinna Polütehniline Instituut	1983	Diplomeeritud elektriinsener
Tallinna 6. Keskkool	1977	Keskharidus

4. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	Tase
Eesti	Kõrgtase
Vene	Emakeel
Inglise	Kesktase

5. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2010-	Tallinna Tehnikaülikool	Assistent
2005-2010	Tallinna Tehnikaülikool	Insener, projekti assistent
1983-2005	Tallinna Tehnikaülikool	Insener

6. Teadustegevus

2011 – 2015 Projekt SF0140016s11 „Aktiivsete elektrijaotusvõrkude muundurite topoloogiad ja juhtimismeetodid“

2009 – 2012 Projekt ETF8020 „Võimsate IGBT muundurite innovatiivsete juhtimis- ja diagnoostikasüsteemide uurimine“

2008 – 2011 Projekt ETF7572 „Võimsad kõrgsagedusliku vahelülga alalispingemuundurid“

2006 – 2007 Projekt EAS656F „Elektertranspordi pardaseadmete toitemuundurid“

7. Kaitstud lõputööd

“Elektromagneetiline transpordiseade” (elektriinsener, 1983, TPI)

8. Teadustöö põhisuunad

Innovatiivset õppetehnoloogiad elektroonika ja jõuelektroonika valdkonnas

9. Teised uurimisprojektid

2006-2008 Projekt IN631 „Elektritehnilise personali täiendkoolitussüsteemi väljaarendamine“

2005-2008 Projekt IN577 „Interdistsiplinaarse ja rahvusvahelise meeskonna- ja projektipõhise õppe rakendamine elektriajamite ja elektroonika, automaatika ja mehhatroonika valdkonna magistriõppes“

**DISSERTATIONS DEFENDED AT
TALLINN UNIVERSITY OF TECHNOLOGY ON
*POWER ENGINEERING, ELECTRICAL ENGINEERING,
MINING ENGINEERING***

1. Jaan Tehver. Boiling on Porous Surface. 1992.
3. Endel Risthein. Electricity Supply of Industrial Plants. 1993.
4. Tõnu Trump. Some New Aspects of Digital Filtering. 1993.
5. Vello Sarv. Synthesis and Design of Power Converters with Reduced Distortions Using Optimal Energy Exchange Control. 1994.
6. Ivan Klevtsov. Strained Condition Diagnosis and Fatigue Life Prediction for Metals under Cyclic Temperature Oscillations. 1994.
7. Ants Meister. Some Phase-Sensitive and Spectral Methods in Biomedical Engineering. 1994.
8. Mati Meldorf. Steady-State Monitoring of Power System. 1995.
9. Jüri-Rivaldo Pastarus. Large Cavern Stability in the Maardu Granite Deposit. 1996.
10. Enn Velmre. Modeling and Simulation of Bipolar Semiconductor Devices. 1996.
11. Kalju Meigas. Coherent Photodetection with a Laser. 1997.
12. Andres Udal. Development of Numerical Semiconductor Device Models and Their Application in Device Theory and Design. 1998.
13. Kuno Janson. Paralleel- ja järjestikresonantsi parameetrilise vaheldumisega võrgusageduslik resonantsmuundur ja tema rakendamine. 2001.
14. Jüri Joller. Research and Development of Energy Saving Traction Drives for Trams. 2001.
15. Ingo Valgma. Geographical Information System for Oil Shale Mining – MGIS. 2002.
16. Raik Jansikene. Research, Design and Application of Magnetohydrodynamical (MHD) Devices for Automation of Casting Industry. 2003.
17. Oleg Nikitin. Optimization of the Room-and-Pillar Mining Technology for Oil-Shale Mines. 2003.
18. Viktor Bolgov. Load Current Stabilization and Suppression of Flicker in AC Arc Furnace Power Supply by Series-Connected Saturable Reactor. 2004.
19. Raine Pajo. Power System Stability Monitoring – an Approach of Electrical Load Modelling. 2004.
20. Jelena Shuvalova. Optimal Approximation of Input-Output Characteristics of Power Units and Plants. 2004.
21. Nikolai Dorovatovski. Thermographic Diagnostics of Electrical Equipment of Eesti Energia Ltd. 2004.
22. Katrin Erg. Groundwater Sulphate Content Changes in Estonian Underground Oil Shale Mines. 2005.

23. Argo Rosin. Control, Supervision and Operation Diagnostics of Light Rail Electric Transport. 2005.
24. Dmitri Vinnikov. Research, Design and Implementation of Auxiliary Power Supplies for the Light Rail Vehicles. 2005.
25. Madis Lehtla. Microprocessor Control Systems of Light Rail Vehicle Traction Drives. 2006.
26. Jevgeni šklovski. LC Circuit with Parallel and Series Resonance Alternation in Switch-Mode Converters. 2007.
27. Sten Suuroja. Comparative Morphological Analysis of the Early Paleozoic Marine Impact Structures Kärddla and Neugrund, Estonia. 2007.
28. Sergei Sabanov. Risk Assessment Methods in Estonian Oil Shale Mining Industry. 2008.
29. Vitali Boiko. Development and Research of the Traction Asynchronous Multimotor Drive. 2008.
30. Tauno Tammeoja. Economic Model of Oil Shale Flows and Cost. 2008.
31. Jelena Armas. Quality Criterion of road Lighting Measurement and Exploring. 2008.
32. Olavi Tammemäe. Basics for Geotechnical Engineering Explorations Considering Needed Legal Changes. 2008.
33. Mart Landsberg. Long-Term Capacity Planning and Feasibility of Nuclear Power in Estonia under Certain Conditions. 2008.
34. Hardi Torn. Engineering-Geological Modelling of the Sillamäe Radioactive Tailings Pond Area. 2008.
35. Aleksander Kilk. Paljupooluseline püsimagnetitega sünkroongeneraator tuuleagregaatidele. 2008.
36. Olga Ruban. Analysis and Development of the PLC Control System with the Distributed I/Os. 2008.
37. Jako Kilter. Monitoring of Electrical Distribution Network Operation. 2009.
38. Ivo Palu. Impact of Wind Parks on Power System Containing Thermal Power Plants. 2009.
39. Hannes Agabus. Large-Scale Integration of Wind Energy into the Power System Considering the Uncertainty Information. 2009.
40. Kalle Kilk. Variations of Power Demand and Wind Power Generation and Their Influence to the Operation of Power Systems. 2009.
41. Indrek Roasto. Research and Development of Digital Control Systems and Algorithms for High Power, High Voltage Isolated DC/DC Converters. 2009.
42. Hardi Hõimoja. Energiatõhususe hindamise ja energiasalvestite arvutuse meetodika linna elektertranspordile. 2009.
43. Tanel Jalakas. Research and Development of High-Power High-Voltage DC/dC Converters. 2010.
44. Helena Lind. Groundwater Flow Model of the Western Part of the Estonian Oil Shale Deposit. 2010.
45. Arvi Hamburg. Analysis of Energy Development Perspectives. 2010.

46. Mall Orru. Dependence of Estonian Peat Deposit Properties on Landscape Types and Feeding Conditions. 2010.
47. Erik Väli. Best Available Technology for the Environmentally Friendly Mining with Surface Miner. 2011.
48. Tarmo Tohver. Utilization of Waste Rock from Oil Shale Mining. 2011.
49. Mikhail Egorov. Research and Development of Control Methods for Low-Loss IGBT Inverter-Fed Induction Motor Drives. 2011.
50. Toomas Vinnal. Eesti ettevõtete elektritarbimise uurimine ja soovituste väljatöötamine tarbimise optimeerimiseks. 2011.
51. Veiko Karu. Potential Usage of Underground Mined Areas in Estonian Oil Shale Deposit. 2012.

