Comparison of university level study methods and laboratory equipment for teaching of electrical drives

Juhan Laugis, Tõnu Lehtla
TALLINN UNIVERSITY OF TECHNOLOGY
Ehitajate tee 5
19086 Tallinn, Estonia
Tel.: +372 / 620 3700
Fax: +372 / 6203701
E-Mail: laugis@cc.ttu.ee, tlehtla@staff.ttu.ee
URL: http://www.ene.ttu.ee/elektriajamid/

Keywords

«Education methodology», «Drive», «Mechatronics», «Robotics»

Abstract

The paper deals with teaching problems on the university level. Integration of different study fields like mechatronics, electrical drives and industry automation is under discussion. The article compares different classical and modern study methods and laboratory equipment: classical lecture and laboratory courses, virtual Internet-based training and virtual laboratories, project-based learning by doing, self-made stands for experiments, standardized teaching laboratory systems, and industrial component-based laboratories.

Introduction

Last years have seen fast development in information, automation and electronics technologies. New Engineers in industry have to satisfy new demands. Therefore, new challenges for university studies are also urgent. One the other hand, European community has introduced the modernization of education systems in different study levels. As a result of this process, universities of technology in different countries have joined their efforts in the reorganization of their education systems. Many specific questions have raised and numerous practical problems must be solved in connection with this reorganization.

The study of electrical drives is normally integrated with a study of power electronics or industry automation. To improve the organization of the university study process, different study fields must be analyzed and compared to find the ***areas of interaction***. The contradiction between a large quantity of new information and a limited duration of a training course will lead to a search for ***new methods of teaching***. To keep expenditures for education on an accepted level, ***laboratory equipment*** must be carefully selected and optimally used in the study process.

1. Study field and study vector

The study fields of mechatronics, electrical drives and power electronics, robotics or industry automation are very practically oriented. The integration of the mechanical components with the sensors, actuators, electrical drives, logical controllers and information technology are the basis of the new branch of mechanical engineering - mechatronics. One the other hand, the same activity field was established for electrical and systems engineers. An optimal conversion of electrical to mechanical energy is the main topic of study for electrical engineers in the field of electrical drives and power electronics. The integration of electrical machines with modern electronic components and control software leads also to the highway of mechatronics. But the term "mechatronics" is not popular among electrical engineers. Instead of the traditional field of electrical drives, a general term "motion control" was applied during the last years. Most of the industrial technologies are based on different machines and mechanical constructions. Most of electrical energy (60...70 %) is used by drives for conversion to mechanical motion. Fields of mechatronics, electrical drives, robotics are also very close to the field of industry automation, the main field of activity for systems engineers. An overview of interactions between different fields of engineering is shown in Fig. 1.

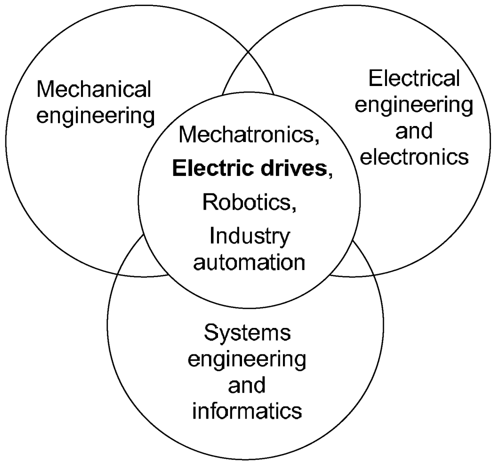

Fig. 1: Interaction of different fields of engineering.

Many new branches of science were born during the 20th century. That century was an era of split in science. During the last years an opposite tendency of integration in science can be noticed. The close interaction of different study fields leads to the idea that the study processes for mechanical, electrical and systems engineers are very closely linked. The possibilities for the integration of study plans for mechanical, electrical and system engineers can be analyzed (as an example) on the basis of curricula for engineering studies of electrical drives and power electronics in the domain of electrical engineering. The study objectives in the fields of mechatronics (domain of mechanical engineering) and systems engineering (domain of informatics) are very close to the study objectives in the field of electrical drives and power electronics.

It is possible to define the study vector in the two-dimensional knowledge world (Fig. 2). This world is illustrated as a plane and axes of this plane are general knowledge or mental outlook and special knowledge or speciality skills. The study subjects are divided between four main sectors: general study, core study, basic study and special study. The right proportion of general and special knowledge or the proportion of mental outlook and speciality skills is the most important dilemma of education on every level of study. This proportion can be characterized by the direction of the study vector on the knowledge plane.

Normally, for the bachelor study the vector is tilted to the axis of general knowledge. For the doctoral study, the vector must be turned in the direction of special knowledge. In the real study process, the direction of this vector can often vary. Special knowledge of every subject must be mapped in the map of general knowledge to provide the right orientation in the knowledge world. The situation with special knowledge dominating in the absence of mapping in the whole knowledge plane may result in university graduates having specialized skills but poor preparation for work in the changing conditions. Another extreme situation when general knowledge is highly prevalent is when the graduates will be unable to work in their own speciality. Limitations to the complex preparation of students are set by the duration of the study process. The maturity of students for independent qualified and responsible work is enhanced with knowledge acquired through different courses and moving layer by layer to a higher level of knowledge.

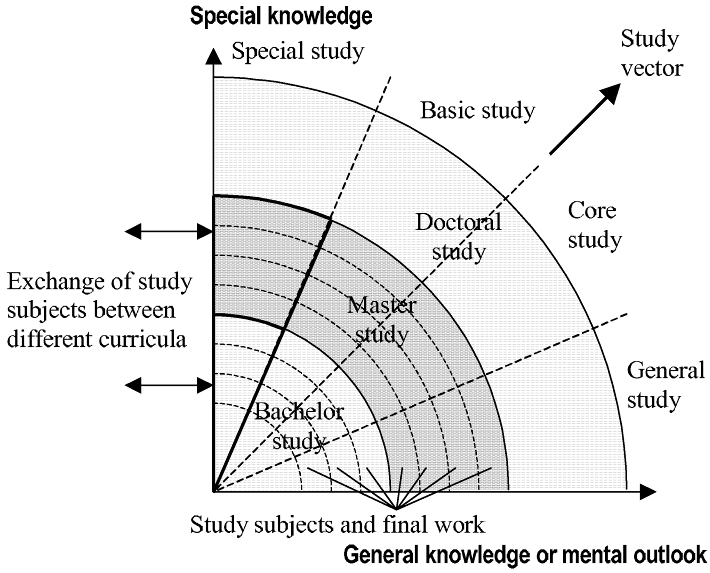

Fig. 2: Knowledge plane and study vector.

2. Curriculum for bachelor and master study

The new common system of European higher education – a three-year bachelor study, followed by a two-year master study (known as 3 + 2 year study) is a special challenge for engineering universities. The former integrated, five-year engineering studies must be re-established on two levels – bachelor and master level. The main problem is the insufficient engineering knowledge and skills of bachelor graduates after three years of study. The university has two main objectives: to prepare students for master study and employers for an engineering field. A question arises - what is the position available for a bachelor graduate in the employment market?

Estonia was one of the first countries in Europe to reorganize its higher education system according to Bologne declaration and establish 3 + 2 year bachelor–master study process. The first experience achieved at Tallinn University of Technology allows us to draw a conclusion that the bachelor graduates are not sufficiently prepared for industry and design enterprise needs, but they can operate as salesmen in engineering sales companies. A more detailed analysis of the curriculum is made on the basis of an example of the curriculum for engineering studies of electrical drives and power electronics at Tallinn University of Technology.

Modularity and flexibility are the two main features of the new study process. These two features guarantee the changeability of study modules and subjects between different universities. The changeability is based on the common credit point (CP) system and European credit point transfer system (ECTS).

Educational aims of the curriculum of bachelor study. Acquisition of knowledge in the following areas: fundamentals of natural and exact sciences in extent of contents and volume needed to acquire fundamentals of technical sciences and knowledge on speciality; fundamentals of technical sciences in extent of contents and volume proper to the field of electrical drives and power electronics which are needed to continue studies on the master level or to work as an engineer and for continuing education; general bases of humanities and social sciences; relations of a human, natural environment and technology to understand the essence of the profession of engineer and its professional responsibility as well as positive and negative aspects of engineering; major sources of professional information and their use; principles to draft engineering projects. Acquisition of skills to express oneself orally and in writing to communicate in one's mother tongue and at least in one of foreign languages; use modern information technology; study, provide and analyze information and evaluate expediency of new knowledge on one's own, arrange work and objectively evaluate its results, implement knowledge acquired in project implementation in the specific field. To prepare students for continuing their studies on the master level study.

Capacity of curriculum:	180 CP by ECTS
Nominal study period:	3 years
Degrees granted:	Bachelor of Science in Engineering

Structure of the curriculum for bachelor study: Total 180 credit points (CP) of bachelor study are divided between the following modules: general studies (21 CP), basic studies (54), core studies (62), special studies (24), free choice courses (6), practice (5), and graduation thesis (8). Most of studies are so-called classroom studies (167), including lectures, exercises, seminars and laboratory practice. More than half of studies (common domain studies 108 CP) are common for all students of power engineering. List of the courses according to curricular parts is shown in Fig. 3.

List of courses

Bachelor study

General studies 21.0 CP	
Philosophy	2.0
Science of risk and safety	4.0
Micro- and macroeconomics	4.0
Academic foreign language	3.0
Informatics I	4.0
Informatics II	4.0

Free choice studies	6.0

Basic studies 54 CP	
Linear algebra	5.0
Mathematical analysis I	5.0
Mathematical analysis II	5.0
Physics I	6.0
Physics II	6.0
Graphic engineering	4.0
Machine engineering	5.0
Electrical engineering I	6.0
Electrical engineering II	6.0
Electrical machines	6.0

Core studies 62.0 CP	
Intro to power engineering	4.0
High-voltage engineering	5.0
Basics of material study	6.0
Applied systems theory	5.0
Microprocessor techniques	4.0
Practice of microprocessors	2.0
Basics of automatic control	5.0
Semiconductor engineering	5.0
Numerical calculations	4.0
Power electronics	5.0
Electrical drives	7.0
Introduction to robotics	5.0
Electricity supply	5.0

Graduation thesis	8.0

Special studies 24.0 CP	
Industry automation	5.0
Technology and drives	5.0
Electrical materials	4.0
Electrical apparatus	4.0
Electro-technology	4.0
Measurement engineering	4.0
Basics of heat engineering	4.0

Practice	5.0

Fig. 3: List of bachelor courses according to curricular parts (modules).

Educational aims of the master study curriculum: to deepen knowledge and understanding in: basic problems and development trends in the specific field, fundamental sciences, economics, social problems, and foreign languages. To develop skills in the analysis and solution of systems problems, experience in searching information and working on literature, skills of scientific disputes, providing profound knowledge for independent research and skills in composing papers, develop abilities, activities and confidence in setting the purpose and critical approaches to creativity. For universities of technology the two main outputs of master studies could be graduates with excellent knowledge of engineering and design or graduates with knowledge and skills in technological sciences.

Capacity of curriculum:	120 CP
Nominal study period:	2 years
Degrees granted:	Master of Science in Engineering

Structure of the curriculum: Total 120 credit points (CP) of master study are divided between the following modules: general studies (20 CP), basic studies (13), core studies (24), special studies (26), free choice courses (7) and graduation thesis (30). These studies include classroom studies (90). Common domain studies are in amount of 33 CP. List of the courses according to curricular parts is shown in Fig. 4.

The bachelor level study is more oriented on general knowledge and skills. Master study must guarantee some special professional skills in the field of engineering design. Generally, the objectives for university level engineering studies can be defined as follows: a bachelor degree holder must have knowledge of engineering in related study field, a master degree holder must be able to create new technology and engineering systems on the basis of existing knowledge. A doctoral degree holder in engineering must be able to generate new knowledge for future technologies.

Different study fields can be integrated by using similar modules (with the same amount of credit points), which contain different optional courses for mechanical, electrical and systems engineers. Different curricula must have a common module of general studies, a flexible module of basic studies, a highly flexible module of core studies, and speciality oriented special modules of study courses.

List of courses

Master study

General studies 20.0 CP
(optional 9.0 CP)

Grounds of law	4.0
Environmental protection	4.0
Business administration	4.0
Communicational psychology	4.0
Product development	3.0
Energy policy	3.0
English for science	3.0
German for science	3.0
French for science	3.0

Basic studies 13.0 CP

Probability theory and mathematical statistics	5.0
Electromagnetic field theory	4.0
Special course of electrical engineering	4.0

Free choice studies 7.0 CP

Core studies 24.0 CP
(optional 12.0 CP)

C & Object-oriented Programming	7.0
Microprocessor control of electrical drives	5.0
CAD of automation control systems	4.0
CAD of electronic devices	4.0
CAD of electrical machines	4.0
CAD of electrical drives	4.0
CAD of electricity supply	4.0

Graduation thesis 30.0

Special studies 26.0 CP
(optional 26.0 CP

Special course of electrical drives	4.0
Special course of power electronics	4.0
Distortions and reliability of electrical equipment	4.0
Marketing and management in electrical industry	4.0
Electrical lighting	4.0
Special course of industry automation	4.0
Special course of robotics	4.0
Workshop on el. drives and industry automation	4.0
Numerical field analysis	4.0

Fig. 4: List of master courses according to curricular parts (modules)

Study methods

Side by side with the classical academic study, many new study methods have been tested recently in different universities. The most popular methods are shown in Table 1. An industry-oriented study allows for the shortest way for students from university to industry, but is not always the best solution for the whole society. During periods of technological revolutions and fast changes in society special competence in a certain type of technology will lose its value when technology or a profound change of economy takes place. Virtual models and computer-based studies are very attractive for young people, but often they are remote from real life. Project-based study generates much synergy and new ideas, but is relatively expensive for a university. Table I provides a SWOT analysis of these methods.

A combination of all of these methods seems to be the most realistic way to set up an optimal study process in a university. Moreover, it will provide a good education to students.

Table I: Comparison (SWOT analysis) of different study methods

	Classical academic study	Industry-oriented study	Virtual, model-based study	Project-based study
Description	Classical academic lectures and laboratory experiments; individual and group study	Application-oriented lectures, laboratory experiments on industrial equipment and practice in industry; individual and group study	Worldwide distance learning, virtual laboratories; individual study via the Internet	Learning by doing and learning by inventing; group study
Strengths	Immediate communication with professional teachers (professors)	The shortest way to real life and the best possibilities for graduates on the labour market	Conveniences for continuous and life-long learning. Wide use of modern info technology; cheapest form of study	Good possibilities for "brainstorming" actions, generation of synergy and new knowledge
Weaknesses	Laboratory (teaching) technology lags behind real industrial technology level	Weak academic basis of knowledge	Weak contact with real life; no direct contacts with professionals	High level of expenditure for laboratory equipment, individual work and particular experiments
Opportunities	Worldwide standardization of the teaching process and industrial production of laboratory equipment	Adaptation of teaching with needs of local industry in the use of industrial devices produced by firms in the surroundings; good cooperation between universities and industrial firms	Development of info technology provides new opportunities for worldwide learning. Time independent and free planned study; best possibilities to combine work and study	Development of students research work; involvement of students into research and invention in the field of engineering
Threats	Play of science in the environment isolated from real life	Knowledge in a specific industrial area and difficulties in retraining	Fear of real industrial world	Weak background of systematic knowledge

The field of industrial electrical drives, robotics, mechatronics or industry automation systems can be described by the structure in Fig. 5. All of these systems control the flow of materials, energy, and information. Main emphasis in the study for mechanical engineers is placed on the mechanical constructions and flow of materials. Electrical engineers must control the flow and the conversion process of energy. Systems engineers must take care of the control of information flow. In industry engineers of these three fields must work together. Therefore, they must learn how to cooperate with specialists in different areas of engineering already during their university studies. The best form for this cooperation is the project-based study. In this case, students of different specialities in one project group will solve a common complex project task. For example, a student project group can design a special construction of a robot. Students in mechanical engineering will find optimal solutions for the construction of a manipulator; students in electrical engineering will design electrical drives with motors, power converters and microprocessor control modules, students of system engineering will generate software modules for robot control systems. The results of design work can be tested during robot competition.

Laboratory equipment

Laboratory practice is an effective means for improving of the quality of education in the engineering domain. But laboratory practice and laboratory equipment for universities of technology is a relatively expensive part of education. Therefore, the amount of laboratory practice and its content must be carefully analyzed.

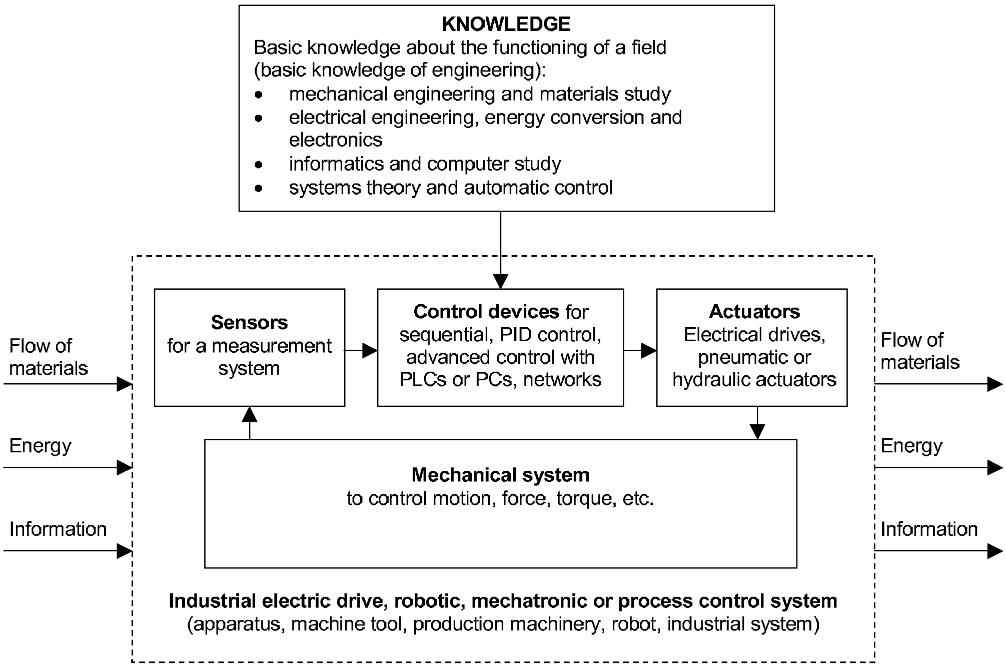

Fig. 5: Common field of operation for different specialists in engineering

List of equipment and software needed for the study process:

- Electronic components and simulators of electronic circuits
- Electrical motors and drives. Power electronic converters
- Programmable controllers and industrial PCs
- Industrial and building networks (Industrial Ethernet, Interbus, Profibus Modbus, CAN, ASI, LON, Instabus (EIB), etc)
- Various sensors and actuators and manifold equipment for intelligent building installations
- CNC controlled machine tools and/or control panels with simulators (software), networking devices of machine tools. Industrial robots and/or their simulators (software), networking devices of robots
- Logistics and transport systems of modern manufacturing, e.g. transport robots, conveyors, and other transport systems. Robot systems for flexible manufacturing systems (FMS)
- Visualization, operation and control software (InTouch and others)
- Artificial intelligence (AI) and recognition of images
- Software for simulation, design and industry management

Conclusions

New trends of technology development will create a demand for the integration of specialities, closer cooperation of different specialists in joint projects.

For technological education the right proportion of general and special knowledge (direction of a study vector) is an important feature for every layer of education.

Stratified and modular structure of study plans allows an integration of different study fields and saving study resources.

Different study methods (classical, industry based, e-learning and project-based) could be integrated and used together in optimal proportion to save time, financial and equipment resources.

Common laboratory basis for different study fields helps their integration and saving equipment resources.

Project-based study could be an important step for the development of students research activities.

References

[1] L. Liivik, R. Jansikene, and T. Lehtla. Topical problem of Teaching of Electrical Drives. 11th International Conference on Power Electronics and Motion Control - EPE-PEMC 2004 Riga. Proceedings Vol. 4 pp. 502-506.

[2] B. Davat, P. Bauer, and P. Van Duijeen. Teaching of Power Electronics: From Graphic Representation to animation. 11-th International Conference on Power Electronics and Motion Control - EPE-PEMC 2004 Riga. Proceedings Vol. 4 pp. 436-441.

[3] T. Nobels, W. Deprez, I. Pardon, S. Stevens, O. Viktorin, J. Driesen, J. Van Den Keybus, and R. Belmans. 11th International Conference on Power Electronics and Motion Control - EPE-PEMC 2004 Riga. Proceedings Vol. 4 pp. 442-446.

[4] J. Laugis and T. Lehtla. Mechatronics – a new study field or a new branch of science and engineering? 10th International Conference on Power Electronics and Motion Control - EPE-PEMC 2002 Dubrovnik.