Microsystem Research Work at the University

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Abstract: - The paper describes methods of active involvement of students in research work and application of research work results in educational process at the same time. Several workplaces are described in detail where students work on defined tasks. Individual tasks represent partial solutions of large research projects. Student work methods and result presentations are presented. Stress is laid on individual work. This paper deals with questions concerning teaching microelectronic courses, more precisely courses connected with the area of microsystems, at a technical university. Educational methods based on individual students' projects are described. Attention is focused on arrangement of individual courses, output form of students' projects, ways of increasing education efficiency and time utilization, material, functional, technical and instrument support of individual projects and link-up to international cooperation. Most effort is devoted to individual students' projects, their natural motivation in selecting courses and realization of projects.

Key-Words: - Microsystems, Design, Education, Microelectronics, Communications

1 Introduction

At the university, education in microelectronics and microsystems (MST) is very closely linked with domestic and foreign research projects. The most important projects are supported by the Ministry of Education, Grant Agency of the Czech Republic and University Development Foundation. With support of the Ministry of Education, the research laboratory Centre of Microsystems (CEMIS) was established. Its activity is focused on development of microsystems for applied research and development with close link to their practical applications - Fig. 1.

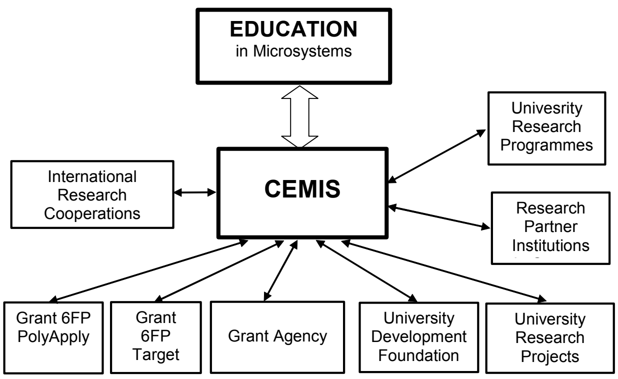

Fig.1 Project links to the Centre of Microsystems

The project has been coordinated with research activities performed in the frame of research programs solved at the university. During project solving, international contacts for extension of information networks as a source of current and future technological and technical links have been used.

From the point of view of applications, the microsystems opened new opportunities practically in all areas. Great attention is focused on their development as it was focused on development of integrated circuits in the 1970ies and 1980ies. For example, in medicine there are being developed microanalysers of gas in blood that are implantable into human body, micropumps for improvement of blood circulation functionality, implantable systems for automatic insulin dosing in human organism. As an example of application for telecommunications we can mention an intelligent matrix of micromirrors for optical communications realized at the university. There is worth mentioning cooperation of university researchers on development of new generation of pacemakers.

Microsystems include three basic functions that are represented by corresponding elements or systems fulfilling these functions. Function of measuring and sensing information about physical or chemical environment is realized by „microsensors“, effects on the environment are realized by „microactuators“; and function of intelligent information processing and microactuator control is realized by circuits of signal processing. For realization of these systems, technology of integrated circuit processing combined with special microsystems technologies is applied. Realization of microsystem can be performed on one or more chips, similarly as integrated circuits are realized [1].

In principle there exist several different approaches to education of students in the area of Microsystems that influence and support each other. Purpose of this variability is search for ways, which can make study for students instructive and interesting at the same time. One of the basic and important ways is direct involvement of students in research work using direct link of some courses to research projects. Results of students’ work are part of their individual projects. The students defend these projects at the end of term in the frame of corresponding course. In addition, the student’s results contribute to solutions of corresponding research projects. Another way is leaving greater variability in selection of individual project topics. In that case, solved topics are usually parts of research topics less frequently – Fig.2.

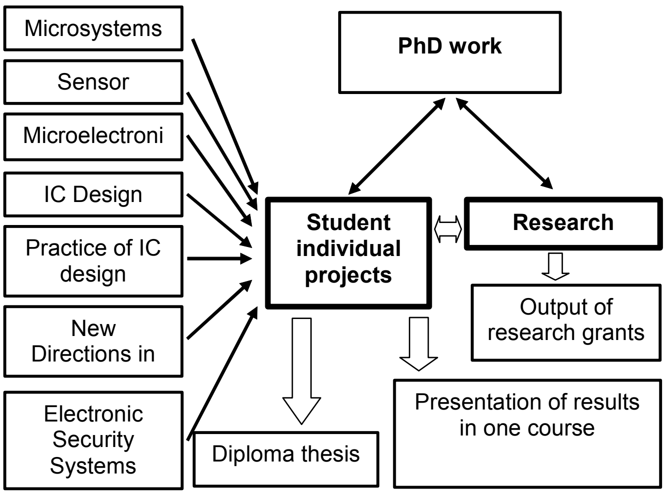

Fig.2 Links of courses to projects and share of student’s special work

At present, education in microelectronic courses is a hot topic. In addition to "classical" integrated electronic circuits, more attention is focused on integrated microsensors, produced in hybrid or monolithic technologies. Microsystems - new direction in interdisciplinary approach to electronic development - represent further step forward. These problems are very interesting for students because they continuously bring new and progressive solutions and knowledge. A number of students express interest in this area in case of concrete practical tasks (i.e. solving various circuit connections based on elements available on the market). Students like to see real results that are immediately applicable in practice (measurement, control, etc.). Introducing project-oriented education has resulted in increased number of students in individual courses, namely in Sensor Systems, Microsystems, New Directions in Electronics, Microelectronics, Design of Integrated Circuits, Electronic Security Systems.

2 Research tasks as part of education

Some courses, that are introducing problems of microelectronics, include in their practical part student research work. Students participate in solving partial tasks of larger research projects, they become members of research teams. Level of participation depends on student’s activities, his/her previous results and especially current work. Students present their research work results in the form of short presentations and discussions in the frame of individual courses.

If the student work results in “tangible” and measurable” outputs, as for example realised part on the PCB board (e.g. electrical model of micromirror structures), then such results are used directly or after slight modification as measuring and demonstration tools. This approach to student work is applied in the following courses: Sensor Systems, Electronic Security, Microelectronics, Applications of Microelectronic Elements, Power Supply in Electronics, etc.

2.1 Ways of students’ research activities

Students’ involvement in research activities is performed in many ways that differ in a number of basic factors. Students are free in their decisions; they are not forced to participate in this work. However, it is recommended to do so.

The research activities, projects and students’ research activities are discussed on many levels, namely in education, during discussions with students, etc. Students get extended information about potential involvement in research activities.

In curricula, there is a number of specialised courses utilising principle of project-oriented education. In these courses, the students get frequently task specifications that represent partial projects being parts of larger research projects.

Topics of Master theses are usually based on actually solved projects at the Department. However, there is a disadvantage of long realisation time of such a task.

Nominal interval from defining topic of the Master thesis to its finishing is two years, but in recent years relatively many students ask for postponing the delivery. On the other side, if the student is good and teacher's supervision works well, the results acquired in the thesis may be usable in research projects. Efficiency of results applicability is very heterogeneous, in average it can be estimated to be up to 30 per cent. Here we are facing the problem that not all students have the sense of responsibility to deliver good work. There are students who just try to do their work "somehow" – to satisfy the basic requirements with as little effort as possible.

Students as young researchers. The university enables talented students having interest in research work to work in specialised laboratories as so-called student researcher. These young researchers are in this way included in research teams and usually get small part of the project to solve. In this spontaneous way the students are involved in problem solving, they have to learn to communicate with larger team, formulate requirements to input and output information, express in writing and graphically results of their work. These students get a certain amount as scholarship rewarding their work that motivates them for quality work. A number of these students decide to apply for PhD study after they finish their undergraduate study.

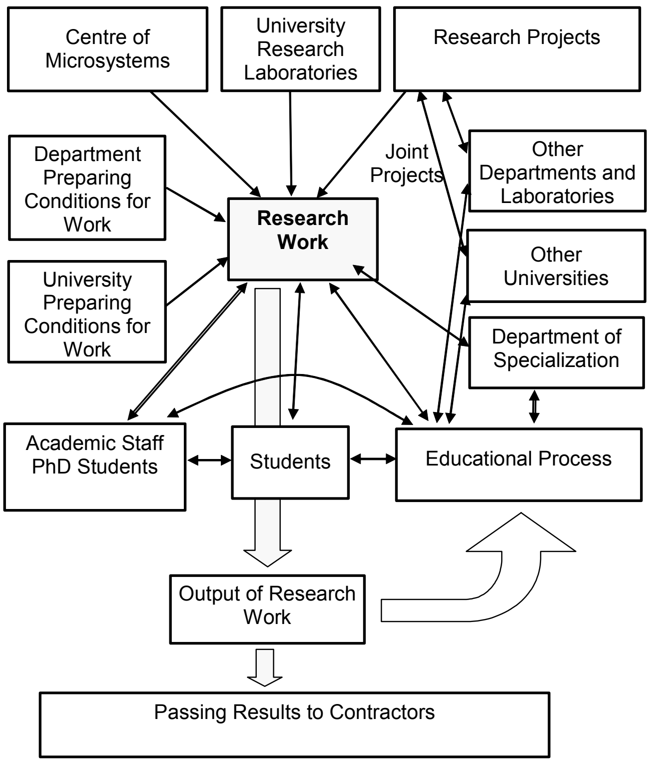

Fig.3 Interconnection of student education and research

Students' involvement in specialised work in the frame of individual studied courses. In several courses, the students can choose the form of passing the "practical part" of the course, i.e. laboratory work. They can select between theoretical and practical work [1]. In the frame of this laboratory work, the students can realise other research activities than those solved at the corresponding department as well. For example, students who work during study in a certain company, or a research institute and solve a specialised R&D problem can solve part of the problem in the frame of the corresponding course. They can use all materials and devices of the department, or other laboratories of the university. Interconnection of student education and research activities are depict on Fig.3.

2.2 Basic workplaces for student research

In the CADENCE design centre, software systems CADENCE, HSPICE a CoventorWare for design, modelling and simulation of integrated circuits and micromechanical microstructures are used. Laboratory for electronics CAD is equipped with PC and SUN workstations. Worldwide standard design software is implemented here: CADENCE, SYNOPSIS, HSPICE, XILINX. As a EUROPRACTICE member, the department has access to European integrated circuits processing plants (ASIC Multi-Project Wafers runs), such as Alcatel Mietec, Austria Mikro Systeme, ATMEL-ES2 technologies.

The laboratory of diagnostics and microsystems is determined for measurement and testing of realized microstructures, both on-chip and encased samples of microsystems and microsensors. The laboratory is equipped with a number of instruments.

Optical microscope workplace is used for inspection of micromechanical structures. For processing of graphical information from the microscope, a PC for image saving and software for graphics processing is used. The workplace is completed with reproduction equipment. A TV set is used for displaying manipulation with samples, monitoring moving events in microsystems, and demonstrations for students. A video recorder is used for recording these events.

Workplace for temperature measurements is intensively used for research activity, mostly microsensor calibration. The core of the workplace for development of temperature microsystems with high resolution and accuracy determined especially for biomedical purposes is represented by exact temperature calibrator 140SE-RS.

The core of the workplace for high-speed collection of sensor data is represented by portable high-speed multichannel digitizer OMB-WAWEBOOK-512 with OMB-WBK20 interface that is determined for fast multichannel collection of sensor data and their evaluation on a connected PC.

The workplace for biochemical measurement on microsystem structures is determined for testing of properties of biochemical microstructures, realized on semiconductor base (e.g. pH measurement at ISFET structures).

The workplace of surface assembly allows manipulation and soldering of microelements and realization of professional electronic modules. It is a supporting workplace that is used for realization of additional works during development of measuring systems and devices for diagnostics and measurement.

2.3 Acquisition of theoretical MST knowledge

To succeed in research work, the students must have corresponding knowledge. They acquire this knowledge in several ways, namely studying specialised courses, studying literature and active knowledge acquisition outside university. Prepared structured study is conceptually designed in such a way that students will get knowledge in courses linked to chains. Courses in higher years of study build on knowledge acquired in courses before. Let us mention an example of knowledge acquisition in the area of microelectronics, or microsystems. Individual courses are composed in such a way that the students proceed from theoretical courses with broad fundament to more practically oriented courses. In the end of the study application-oriented courses are studied.

Fundamentals of microsystems (principles of operation of semiconductor elements, circuits, electronic blocks and measurement methodology) are included in several courses in the Bachelor study branch „Electronics and Communication Technology". Basic specialized courses are supported by theoretical courses in mathematics and physics. Bachelor acquires basic theoretical and practical knowledge necessary for applications. Acquired knowledge enables understanding of sensors operating as physical, chemical and biochemical converters. Students get information about technologies, measurement methods and CAD. Individual courses are closely linked together and support each other. They constitute basic knowledge in the area of electronics and microelectronics. They prepare students for further study of Microsystems. Study concept in Bachelor study branch „Electronics and Communication Technology" is illustrated in Fig.4.

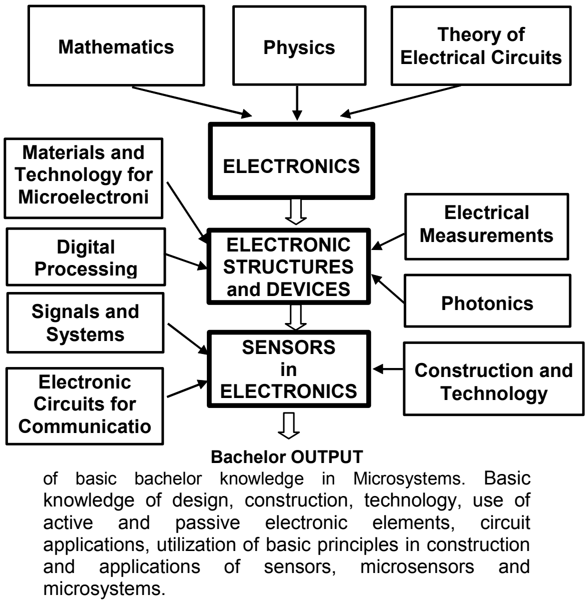

Fig.4 Bachelor courses supporting MST education

In master study, considerably more attention is focused on microsystem technologies. Knowledge acquired in Bachelor study is extended and deepened. Microsystem study is concentrated in the study branch of Electronics (and in its specializations), however it has links to other Master study branches. The core is concentrated in obligatory courses in the specialization dealing with IC and microsystem design. Structure of courses concerning microsystems is illustrated in Fig.5.

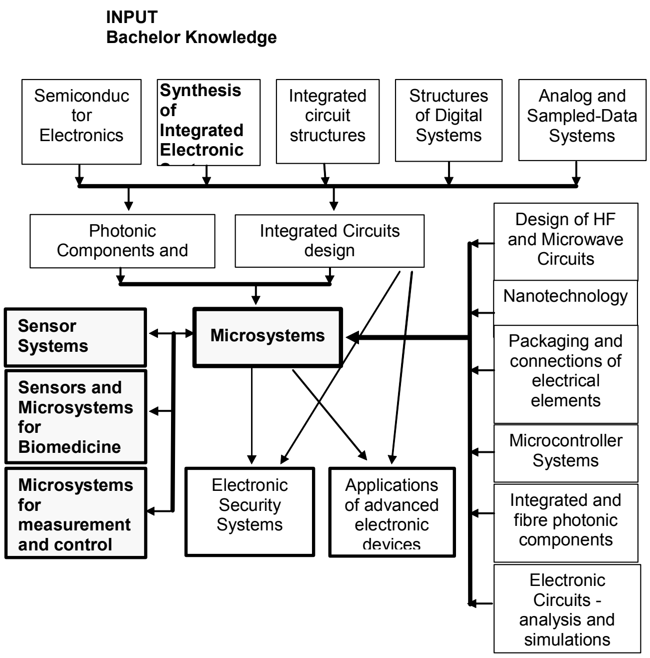

Fig.5 Concept of basic master MST courses

Obligatory courses are completed with recommended optional courses available in the branch of Electronics and other branches. The whole education concept is completed with specialization focused on construction of electronic and fotonic elements that adds knowledge of technology and technological simulations to microsystem education. In the courses, laboratory equipment for microsystem design and diagnostics is used.

3 Application of research results

Results reached by students at solving scientific problems are presented by students and usually applied in various forms. Students are taught to be able to present and defend their results effectively. Various forms and approaches to presentation and application of student research work are listed in the following paragraph.

Students are co-authors of articles in journals or papers on conferences [2]. They present results of their work in front of their student fellows in the frame of the project-oriented courses. They are members of project research teams, their names appear on the member list when defending project results (project review). Results of their work, or participation in solving research projects are considered in final evaluation of the students in individual courses or the whole university study. The best students are awarded by various prices (e.g. SIEMENS price for the best Master thesis). They are preferred when they apply for PhD study, or study abroad. Students with very good results are offered scholarship for study at foreign universities.

Individual student project as a means of more active student's involvement into educational process can contribute to increase of student's interest in study. To invite student's interest in study, it is necessary to define exact rules, inputs and outputs. If it is completed with student's motivation, i.e. concrete output that serves as motivation then usually such courses become more attractive. Such motivation leads to deeper study of given topics and successively to acquisition of larger volume of knowledge [3].

3.1 Contributions of undergraduate students' involvement in research activities

- Motivation increase
- Increase of study attractiveness
- Formulation of input and output information, result presentation, formulation of results and problems at work
- Extension of specialised knowledge
- Linking theory and practice directly during study
- Getting acquainted with real system of solving research projects and their organisation
- Specialised activity leads to increased interest in PhD study; students start their PhD study with clearly defined concepts
- Improvement of communication and presentation skills
- Students are often source of new ideas, ways of problem solving, unconventional approaches to solving given problems
- Thanks to active participation in project solving, formulating ideas and solutions, the students are surer in educational process, they do not study superficially, but they are motivated to knowledge deepening
- Students see direct link between educational process and research work. Study is more interesting and motivating for them if they see that theoretical knowledge is directly applied to practical work
- Acquisition of deeper knowledge
- Possibility to apply engineering approach to work, i.e. from initial definition over design, realization, measurement, documentation to presentation (project defence)
- Students become research team members
- Mutual cooperation of students
- Literature and WWW background research
- Improvement of communication and presentation skills
- Learning of concept definition in the given topic, effective search for ways and means of given problem solving
- More intensive cooperation of students and teachers

4 Conclusions

Equipment of microelectronic laboratories enables the students to collaborate actively during solving partial research tasks. They can use expensive devices. Results of their work contribute to solutions of complex research projects. They are supervised by experienced researchers and professors. Recent results of teaching process efficiency show that students are very much interested in this way of education both from the point of view of time efficiency and concentrated way of work. It is an example of possible way of teaching whose aim is to attract more students to the studied subject. It is necessary to realize that there is no uniform pattern and in all cases it is necessary to consider specificity of individual courses, faculty and last but not least teacher's personality. Even in project-oriented education teacher's personality is dominant. This way of work supports independent student’s work on one side, teamwork on the other one, formulation of workflow, result presentation, etc. It is good motivation of students for natural improvement of their knowledge and experience.

5 Acknowledgements

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