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Aspects of STEM Education in the Design of Devices on Microcontrollers and FPGAs

Iryna Svyd
ORCID 0000-0002-4635-6542
dept. Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
iryna.svyd@nure.ua

Valerii Semenets
ORCID 0000-0001-8969-2143
dept. Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
valery.semenets@nure.ua

Oleksandr Vorgul
ORCID 0000-0002-7659-8796
dept. Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
oleksandr.vorgul@nure.ua

Ivan Shevtsov
ORCID 0000-0002-8528-6540
dept. Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
ivan.shevtsov@nure.ua

***Abstract*—Nowadays the system of engineering and technical education is facing acute challenges of today. Innovative technologies confidently occupy leading positions in society. But there is still a significant shortage of qualified specialists for STEM fields. The paper considers the introduction of elements of STEM education in the laboratory practice of designing devices on microcontrollers and programmable integrated circuits. The comprehensive approach of STEM education allows in the laboratory practice to expand the horizons and awareness of students in relation to the tasks of work. Also, these developments can be scaled to tangential educational components.**

Keywords—STEM, education, integrated approach, laboratory base, higher education, device design, microcontrollers, FPGA.

I. INTRODUCTION

The system of engineering and technical education requires from institutions of higher education (HEIs) appropriate personnel, material and technical, informational and methodical support. Such education should also take into account promising approaches to the training of specialists based on the implementation of aspects of STEM education. STEM education is crucial because of the demand for IT professionals, programmers, engineers, etc. The professions of the future are related to technological production at the interface with natural sciences. Also, the introduction of elements of STEM education into the educational process will allow students to expand their participation in research projects of university departments, workshops, etc. The educational process should be practice-oriented, motivate students to create their own projects and developments, with the aim of developing critical thinking, creativity, spreading the problem-based approach in education, self-education, education throughout life.

The Department of Microprocessor Technologies and Systems (MTS) of the Kharkiv National University of Radio Electronics (KHNURE) conducts fundamental training of specialists in the field of designing devices on microcontrollers and programmable logic integrated circuits (PLCs) [1-6].

According to the results of the development of educational, methodological and practical materials, the lecturers of the MTS department propose to analyze the prospects of applying a new model of education in the field of science and technology - STEM. The acronym STEM stands for four directions: science, technology, engineering, and mathematics.

Strengthening the role of STEM education is one of the priorities of education modernization, an integral part of the state policy to increase the level of competitiveness of the national economy and the development of human capital, one of the main factors of innovative activity in the field of education that meets the demands of the economy and the needs of society.

STEM education is aimed at the development of the individual through the formation of competences, a natural and scientific picture of the world, worldview positions and life values using an interdisciplinary approach to education based on the practical application of scientific, mathematical, technical and engineering knowledge and skills to solve practical problems for their further use in professional activities.

The use of the leading principle of STEM education - integration, allows to modernize the methodological principles, content, volume of educational material of technical cycle subjects, technology of the learning process and form: skills of solving complicvated (complex) practical problems, critical thinking, creative qualities and cognitive flexibility, organizational and communication skills, the ability to assess problems and make decisions, readiness for a conscious choice and mastery of a future profession, a holistic scientific worldview, technological and engineering competencies, mathematical and natural literacy, research and practical skills, etc. An important role consists in the integrative approach to the implementation of STEM education, where significant attention is paid to consistent, thorough, high-quality teaching of educational components

of mathematical, technical, engineering and scientific direction.

The development of STEM education in educational institutions can be implemented at the following levels [7]:

- primary – stimulation of curiosity and support of interest in learning and the search for knowledge, motivation for independent research, creation of simple devices, constructions, scientific and technical creativity;
- basic – formation of persistent interest in natural and mathematical subjects, mastering of technological literacy and problem solving skills, involvement in research, invention, project activities, which will make it possible to increase the share of those who seek to choose scientific, technical, engineering professions;
- profile - in-depth mastery of the system of knowledge and skills of STEM education using methods of scientific research, implementation of innovative projects;
- higher/professional – formation of specialists in various scientific and technical, engineering professions on the basis of institutions of higher education, as well as improving the professional skills of pedagogical workers in the implementation of new teaching methods, relevant courses and implementation of innovative projects.

II. The Main Part

The MTS department teaches the educational component "Design of devices on microcontrollers and programmable logic integrated circuits", which consists of the following modules: "Modeling of digital signals using MATLAB and VHDL"; "Microcontrollers"; "FPGA" [1-6].

Given that STEM education is focused on interdisciplinary connections and applied nature, all this fits very well into the concept of the educational component "Device Design on Microcontrollers and Programmable Logic Integrated Circuits" [8].

The module "Modeling digital signals using MATLAB and VHDL" aims to: study the mathematical foundations of digital signal processing and master the basic algorithms used for the analysis and synthesis of digital signal filtering devices.

The "Microcontrollers" module aims to: study programming of modern STM32F407VGT microprocessors produced by the ST company in C++ language, in-circuit debugging of microprocessor software. Considerable attention is paid to learning the programming language, working with the IAR Embedded Workbench for ARM and STM32CubeMX software packages, for writing and debugging programs, and the use of these microprocessors in digital devices for transmitting and processing information.

The "FPGA" module aims to: study the architecture and programming of modern programmable logic integrated circuits (FPGAs) of the Artix-7 family manufactured by Xilinx, the VHDL digital device design language and debugging methods and tools using Vivado CAD software; use of FPGAs for the development of digital signal processing devices.

One of the approaches to the implementation of STEM education within the educational component "Designing devices on microcontrollers and programmable logic integrated circuits" can be to replace classic laboratory work with design tasks of various levels of detail for individual or team performance. Such design tasks can be developed within the framework of one module or within the framework of end-to-end design of the entire educational component [9-14].

Examples of such project tasks can be:

- for the module: development of a software product in C, C++ for implementing the Butterworth filter of the 3rd order using MATLAB; development of files to create a bandpass filter with a linear phase-frequency characteristic of the first type for implementation on a crystal when using VHDL using MATLAB; to develop a door opening signaling device in the laboratory on the STM32F407VGT microprocessor; develop a low-pass filter with the specified parameters when using the Nexys 4 DDR Artix-7 FPGA Trainer Board, etc.;
- for the educational component: design of a simple information transfer system between two devices using a wireless interface; design of a door opening notification system; designing a device for encoding/decoding information based on PWM modulation, etc.

One of the examples of the effective implementation of STEM education is the implementation of research projects in the educational component "Designing devices on microcontrollers and programmable logic integrated circuits". Students of higher education, under the guidance of lecturers of the educational component, as part of the acquisition of declared competences, carry out research and cross-cutting projects. These projects are presented for approval and protection at university conferences, forums, seminars, exhibitions, etc. According to the results of research projects, students of higher education under the guidance of lecturers participate in publishing activities [15-17].

Conclusions

The implementation of elements of STEM education within the educational component "Designing devices on microcontrollers and programmable logic integrated circuits" demonstrates the effectiveness of learning the material, interest in the implementation of practical tasks, motivation to study, development of research skills, etc.

This is confirmed by the active participation of higher education students studying at this educational component in competitions, hackathons, exhibitions, conferences and forums, and, in particular, is expressed through publishing activities [15-17].

Successfully mastering the elements of STEM education as part of the educational component allows students of

higher education to acquire the necessary skills for more successful job interviews.

Thus, all of the above demonstrates the effectiveness of introducing elements of STEM education into the educational process.

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