University Curricula Modification Based on Advancements in Information and Communication Technologies

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Abstract. This paper discusses the main methods for modification of university curricula for graduate students based on advanced research results in information and communication technology (ICT), artificial intelligence, control, and decision making. Special attention is paid to classifications of the approaches and their evaluation. Examples from the Washkewicz College of Engineering at Cleveland State University, and Black Sea State University, show the efficacy of the authors' proposals, approaches, and classification results.

Keywords: computer science, curricula, knowledge transfer
Key Terms: InformationCommunicationTechnology, Educational Process, KnowledgeEngineeringMethodology, Academia

1 Introduction

Many countries are reforming their science and technology systems to implement the recent advanced achievements of distinguished researchers from their own country and abroad in higher education [10, 13, 14]. At the same time, those of us directly involved in the reform process realize that some countries are deficient in devising genuine exchange programs, both within the country and abroad.

During the last few decades, university and industry researchers from different countries have paid much attention to the modification and development of new artificial intelligence techniques and optimization methods, especially for control and decision making systems [17, 21, 26, 27, 33, 38, 43]. Many international conferences, congresses, symposia, and seminars are specifically devoted to the needs of inter-university and university-industry cooperation [22, 40] in the field of soft computing, fuzzy systems, evolutionary optimization, and artificial neural networks, which allow for the solution of many practical tasks that include uncertainty. These research efforts include the development of new theoretical methods, advanced devices and equipment, joint research projects, joint publications, the incorporation of research results in university curricula, and so on, and also include the determination of the

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most efficient means by which these goals can be achieved. Many publications in the educational field are devoted to the following topics.

(a) Using modern information and communication technology (ICT) in training processes [7, 8, 23, 24, 39], and developing new teaching methods, infrastructures, and software for ICT education and application;

(b) Creating university curricula [29, 30, 31, 32, 42] with balance between theoretical and practical components, and with possibilities for modification in the near future according to new requirements and developments;

(c) Developing new teaching methods and tools for on-line learning [13, 14];

(d) Using modeling and simulation techniques [34] for the investigation of the different dynamic and uncertain processes in education.

The optimization of fuzzy algorithms and systems opens up opportunities for cooperation and collaboration between scientists from different countries. At the same time, university curricula needs constant modification based on new research results in the fields of ICT and computer science to improve the quality of student training. This modification must take into account the dynamics of society's economic development, regional peculiarities, the increasingly intellectual level of technological and production processes, the complexity of market relations and the labor market, and the globalization and internationalization of societies and educational systems [1, 2, 3, 6, 25]. Such constant modification is possible by introducing new fundamental and elective courses, or by content modification of existing courses, taking into account that the present educational systems in many countries allows for elective courses.

The aim of this paper is to review the analysis and evaluation of modern educational approaches for creating and modifying university curriculum in the sphere of ICT, artificial intelligence, evolutionary optimization, automatic control, decision-making, and intelligent robotics. These educational approaches correspond to the recent results in research and science, and are based on the authors' experience in the Department of Electrical Engineering and Computer Science at Cleveland State University (CSU) in Cleveland, Ohio, USA [44], and the Department of Intelligent Information Systems at Petro Mohyla Black Sea State University (BSSU) in Mykolaiv, Ukraine [45].

The rest of this paper is organized as follows. Section 2 deals with related works and section 3 presents a classification approach to advanced scientific and engineering achievements. Section 4 considers the most efficient methods for curriculum modification. Section 5 is devoted to approaches for knowledge transfer, and Section 6 discusses evaluation. Section 7 provides some concluding remarks.

2 Related Works

Here we consider current research in curriculum development education challenges [35, 41, 42]. Some research is devoted to the modification of well-known educational approaches, but some is devoted to the development of new approaches based on the results in ICT and educational methodology [7, 8, 23, 24]. The overview, analysis, interconnection, and correlation of general education reform and the computer revolution is given in [10, 23, 35, 42]. Previous research includes investigations into the role of inquiry as an organizing theme for science curricula [1], the anatomy of narrative curricula [4], the advantages of problem-based curricula [6], the correlation of course and curriculum design with learning outcome assessment at the course and curricular levels [5], the suitability, evolution, and impact of online learning, especially in ICT [13], and the issues, challenges, and opportunities for internet-based curriculum and individual courses [2].

Particular attention in the scientific literature has been devoted to the problem of interdisciplinary research and education, the development of integrated engineering curricula [12] with links between distinct disciplines, new approaches for teaching ICT to the next generation of students [25], embedding employability into curricula [16], and efficient approaches to internationalize university curricula [26]. Other research includes investigations into research-based curricula in response to needs from government agencies and members of the research community [3].

Curriculum modification according to current research is common but different (in some aspects) among various countries, so it is important to share best practices at the international level. The education community needs a wide spectrum of approaches and tools to increase the quality of university graduates and to imbue them with modern knowledge at each stage of their training, based on the latest theoretical and experimental research.

3 Research that Significantly Impacts Higher Education

Here we consider several items due to their significant influence on the higher education and training of graduate students. These items are all related to scientific and engineering research, and can be divided in 4 categories.

1. New directions and recent achievements in science and technology:

a) New theoretical results, including methods, models, algorithms, principles, approaches, etc. [18, 26, 27, 37, 38, 43] (e.g., biogeography-based optimization, invasive weed optimization, and other evolutionary optimization methods; new reliability assessment methods for critical computer systems; etc.).

b) New experimental results that demonstrate theory or scientific phenomena in simple and informative ways (e.g., thermoacoustic engines, ecopyrogenesis, intelligent robots, etc.).

2. Recent products of advanced industrial manufacturing:

c) New devices with improved characteristics and properties that allow investigation into scientific phenomena, and that extend the number of experimental modes for experiments related to hydrodynamics, thermodynamics, electrohydraulics, electromagnetics, nanotechnology, and others (e.g., NAO humanoid robot, IMS radiation detection based on gamma ray spectrometry and the Nerva LG robot, etc.).

d) New electronic components, sensors, and materials that can be used to design next-generation devices (e.g., new slip displacement sensors, FPGA-based controllers and electronic devices, etc.).

3. New software solutions developed by leading and advanced IT companies:

e) New computer-aided design (CAD) software, including 2D and 3D CAD software, that enables new levels of design processes in computer science, computer engineering, device design, machine design, ship design, and other important manufacturing fields (e.g., Active-HDL, Siemens PLM Software, parcel shipping software, etc.).

f) New information and communication technologies for industrial applications and domestic use, including IoT - the internet of things (e.g., Verizon IoT Solutions, Cisco IoT System, etc.).

4. Recent achievements in education based on the modern information and communication technologies:

g) New software and information technologies for teaching more efficiently, testing student knowledge, modeling object behavior in uncertain environments, control, identification, and decision making in education (e.g., e-learning and e-testing information technologies, etc.).

h) New educational methods using the internet to increase motivation and educational efficiency, to teach students to train themselves, and to apply current international standards to education (e.g., miscellaneous electronics and software - MPLAB from Microchip – for the course "Embedded Systems", etc.).

Information about the above items can be obtained by students and teachers from various sources, including the following.

a) Publications in the scientific literature, including articles in international and domestic journals, chapters in monographs and edited books, and abstracts in conference proceedings (e.g., the journals Information Sciences, Kybernetes, etc.).

b) Articles in internet journals with both open access and registration access, chapters in e-books, electronic textbooks, and e-monographs (e.g., open access journals in engineering & computer science, Applied Computing and Informatics, etc.), the journal Sensors & Transducers, Elsevier journals, etc.).

c) Patents from various countries, such as the US, Ukraine, and international (multi-country) patents, with detailed information about new methods of signal processing and new technical solutions for devices in various fields of human activity (e.g., U.S. Patent No.8467921, 2013; Ukraine Patent No. 106288, 2016; etc.).

d) Presentations at conferences, congresses, symposia, and seminars, which in many cases include new and first-hand research results and pre-print material (e.g., ACC 2016, WConSC 2016, CDC 2016, etc.).

e) Industrial reports about new results and achievements that are obtained from industry, associations, or industrial consortia (e.g., NAICS Industry Report Collection, Industrial Report on Samsung Electronics' Processor Exynos, etc.).

f) International and domestic exhibitions of new devices and equipment in various scientific arenas, including new ICT technologies (e.g., Smart City Expo, NANOTECH: Advanced Materials & Applications, etc.).

g) International and domestic research projects that are financially supported by agencies such as the US National Science Foundation, NASA, the Fulbright Program (USA), the Tempus and Erasmus Programs (European Union), DAAD, DFG (Germany), Ministry of Education and Science (Ukraine), etc. [44, 45].

h) Newsletters from professional associations with recent information about new achievements, events, and activities, such as IEEE Spectrum newsletters (Institute of Electrical and Electronics Engineers), the IFAC Newsletters (International Federation of Automatic Control), the Sens2B (Sensor to Business) Newsletter, the E-Letter on Systems, Control, and Signal Processing from the IEEE Control Systems Society, the Medallion e-Newsletter from the PBD Honor Society for International Scholars, etc.

i) Web portals of engineering companies, consortia, and professional associations, such as the smart sensors web portal of the IFSA (International Frequency Sensor Association), web portal of Aldec, Inc. (The Design Verification Company), and others.

4 Research-Based Modification of University Curriculum

Usually a university curriculum consists of a list of year-by-year subjects for student learning, which includes vertical and horizontal relationships and correlation [44, 45]. For example, curricula for undergraduate study at the Department of Electrical Engineering and Computer Science (EECS) in the Washkewicz College of Engineering (WCE) at Cleveland State University are shown in Fig.1 (Bachelor of Science in Computer Science - BSCS) and in Fig. 2 (Bachelor in Electrical Engineering - BEE) [44]. CSU's curricula for the BEE, BSCS, and Bachelor in Computer Engineering (BCE) degrees are approved by the Accreditation Board for Engineering and Technology (ABET). Fig. 1 and Fig. 2 include different notations for required courses, core courses, and electives, as well as interrelations between courses, such as Prerequisite, Co-/Pre-requisite, and Co-requisite.

Analysis of the possibilities for university curriculum modification according to new research results allows us to classify and discuss (using CSU examples) the following educational methods and approaches, which are directed to the improvement of the graduates' qualifications, and which promise to imbue them with modern knowledge in the field of science, engineering, and technology.

New specializations for existing Master of Science programs. New specializations allow CSU to take into account the newest research in science and engineering, and to specify required courses according to new engineering knowledge. For example, specializations in the modern science of nanotechnology has been included in the academic programs of several universities in various countries. The following areas of specialization are offered for graduate study and research in the Master of Science in Electrical Engineering (MSEE) program in the Department of Electrical Engineering and Computer Science (EECS) at CSU.

a) Communication Systems
b) Computer Systems
c) Control Systems
d) Power Electronics and Power Systems
e) Nanobiotechnology

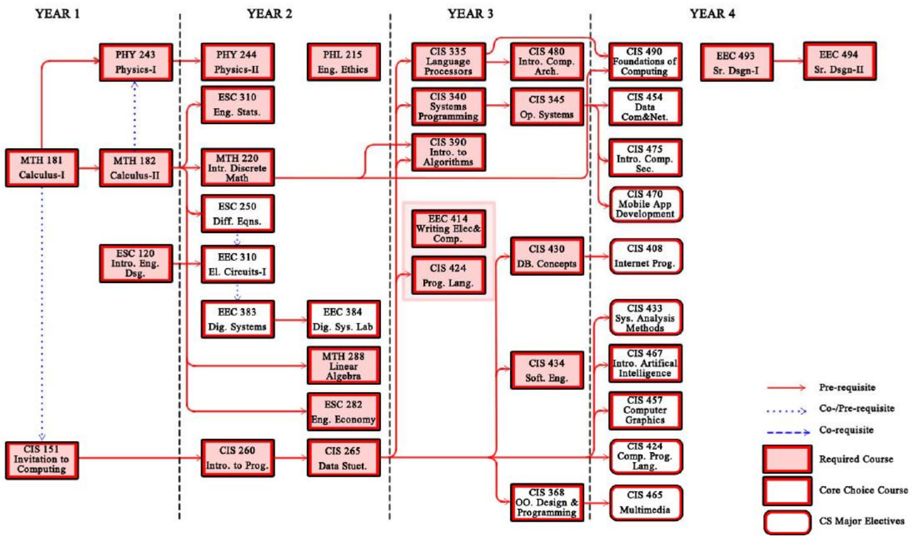


Fig. 1. The BSCS curriculum at CSU

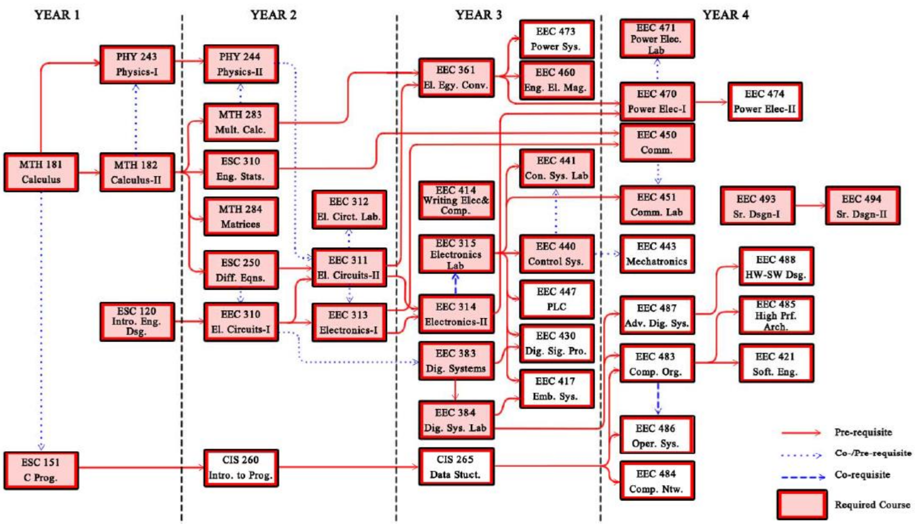


Fig. 2. The BEE curriculum at CSU

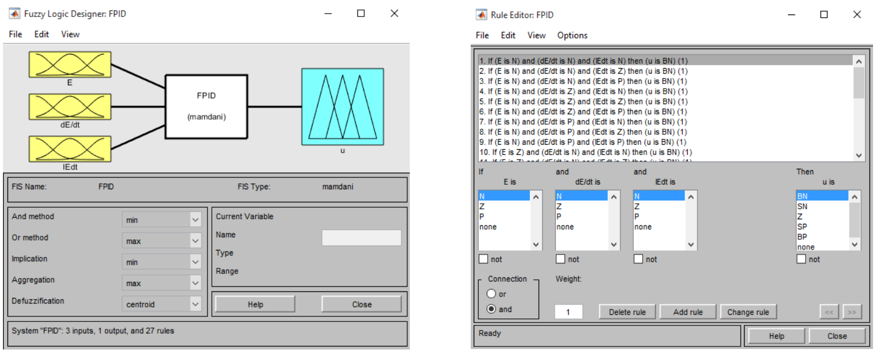
Developing a new Master of Science program. The first example here is the Master of Science in Software Engineering (MSSE) program at Cleveland State University, which is the first of its kind in Ohio, USA. The program introduces students to current and best practices and based on the recent achievements in the engineering of software systems. A distinguishing feature of the program is its emphasis on the architecture, design, quality, management, and economic aspects of software engineering. The program exposes students to new technological developments in an advancing field, and teaches them how to apply their advanced knowledge in the workplace. Graduates meet the modern demands of industry and the needs of information technology professionals, in general, and software engineers, in particular. The second example deals with the computer science track in the Master of Science in Computer Science (MSCS) program at CSU. This track emphasizes the study of computing using the latest technologies, and the graduates of the program are prepared for immediate employment in business, industry, and government, or can pursue higher studies in the discipline. BSSU's MSCS program is preparing the new specialization Methods of Artificial Intelligence.

Doctor of Engineering (DRE) Programs and PhD Programs. PhD Programs in the United States are often theoretical programs which consist mostly of theoretical courses and research. The PhD thesis is a work with a theoretical hypothesis, proposals, and mathematical theorems that are supported, proven, and confirmed by modeling and simulation. The DRE thesis usually includes new models and algorithms for solving specific engineering problems. Compared to PhD programs, DRE programs are more practical, experimental, and industrially oriented.

New elective courses for programs at all educational levels (bachelor, masters, and doctoral). University curricula usually include required and elective courses, with a set of alternatives for electives. In particular, the Master of Science in Electrical Engineering program at CSU includes various sets of elective courses, depending on the specialization. For example, 10 elective courses are available for the Control Systems specialization, including Probability & Stochastic Processes, Embedded Systems, Art and Science of Feedback Control, Advanced Control System Design, System Identification, Nonlinear Systems, Optimal Control Systems, Intelligent Control Systems, Dynamics and Control of MEMS, and Robot Dynamics and Control. Fourteen elective courses are available for the Computer Systems specialization, including Embedded Systems, Software Engineering, Modern Digital Design, Rapid Digital System Prototyping, Formal Methods in Software Engineering, Software Quality Assurance, Software Testing, Software Design & Architecture, High Performance Computer Architecture, Distributed Computing Systems, Computer Networks II, Parallel Processing Systems, Mobile Computing, Secure and Dependable Computing.

Modification of existing courses with new content and teaching methods based on modern software. Here we consider the example of adjusting the content of a Control Systems course by including a new section on Fuzzy Control based on the recent research results, and using the MATLAB Fuzzy Logic Toolbox (Fig. 3) to model control system behavior in different modes and with various disturbances. The teaching approach in the EECS department establishes a spiral framework in which key concepts are revisited at increasing levels of sophistication and interconnection.

New case studies and examples in flexible courses. This approach applies to flexible courses such as Fundamentals of Research Investigations (BSSU, Ukraine), and Writing in Electrical Engineering (CSU, USA). Many engineering examples can be used to teach flexible courses, so it is easy for the instructor to consider new modern engineering examples while taking into account new achievements in the field of electrical and computer engineering, intelligent information systems, and robotics.



a) b)

Fig. 3. Design of Mamdani-type fuzzy PID-controller (FPID) using the MATLAB Fuzzy Logic Toolbox: (a) the structure of the FPID controller; (b) Fuzzy rule editor

New research directions for (a) theses, (b) dissertations, and (c) course projects. Topics of student theses, dissertations, and course projects at CSU and BSSU deal with new research in the field of robotics, artificial intelligence, and control systems, as well as with the current research in the corresponding departments. For example, the EECS department (CSU) received research grants from the US National Science Foundation, Cleveland Clinic, Innovative Developments, Ford Motor Company, American Diabetes Association, and Electronics and Telecommunications Research Institute. BSSU received research grants from the European Commission for TEMPUS for the project Model-Oriented Approach and Intelligent Knowledge-Based System for Evolvable Academia-Industry Cooperation in Electronics and Computer Engineering (2013–2016). Thesis and dissertation research topics include Bio-Inspired Optimization of Ultra-wideband Patch Antennas Using Graphics Processing Unit Acceleration, Applications of Sliding Mode Controller and Active Disturbance Rejection Controller to a PMSM Servo System, and Evolutionary Optimization of Atrial Fibrillation Diagnostic Algorithms.

ICT for lectures and demonstrations. Multi-media plots and program code are efficient ways for introducing ICT and software. For example, consider the lectures concerning optimal state estimation methods [37]. MATLAB plots and demonstrations of the pseudo code are presented in Figs. 4 and 5 for the CSU course Optimal State Estimation.

Teaching and learning in academic consortia. Integrated processes between different universities and colleges is a powerful means for education reforms [10, 34]. Academic consortia allow cross registration (multi-vector) continuous education. The terms “cross registration” and “multi-vector education” mean that students are offered the possibility for parallel study at their home University and elective courses according at other universities [19]. The objective of multi-vector education is to create conditions for the study of both foundational courses and elective courses to meet student inclinations, abilities, aspirations, and desires.

Any curricular innovation based on ICT should be supported by software facilities. For example, the relationship between disciplines and software in the EECS department at CSU can be seen in Table 1, Fig. 1, and Fig. 2.

```
function DiscreteKFEx1(N)
% Discrete time Kalman filter for position estimation of a Newtonian system.
% This example illustrates the effectiveness of the Kalman filter for state
% estimation. It also shows how the variance of the estimation error
% propagates between time steps and decreases as each measurement is
% processed.
% INPUT: N = number of time steps.
if ~exist('N', 'var')
   N = 6;
end
T = 5; % time between measurements
sigma = 30; % position measurement standard deviation
R = sigma^2;
P0 = [100 0 0; 0 10 0; 0 0 1]; % initial state estimate uncertainty
% A = [0 1 0; 0 0 1; 0 0 0]; % continuous-time system matrix
H = [1 0 0];
F = [1 T T*T/2; 0 1 T; 0 0 1]; % state transition matrix
x = [1; 1; 1]; % initial state
xhat = x; % initial state estimate
Q = zeros(3,3);
Q(3,3) = 0.01;
posArray = zeros(1, N);
xhatArray = zeros(3, N);
yArray = zeros(1, N);
Pplus = P0;
Varminus = zeros(1, N);
Varplus = P0(1,1);
KArray = zeros(3, N);
for k = 1 : N
  …
```

Fig. 4: Sample MATLAB code for CSU's Optimal State Estimation course

5 Efficient Knowledge Transfer

In this section we classify the most efficient ways, according to authors' point of view, for knowledge transfer using various combinations: teacher–student, student–student, student–student team, and teacher group–student group. We consider these approaches mostly using examples from CSU.

Invitation of visiting professors. Usually, visiting professors present individual specialties, for example Fuzzy Modeling and Control, Decision Making in Uncertainty, Optimal State Estimation, Intelligent Sensors, Robotics, Biomechanics, Mechatronics, etc. This is an efficient way to give students new knowledge based on research results within the framework of regular classes or special classes.

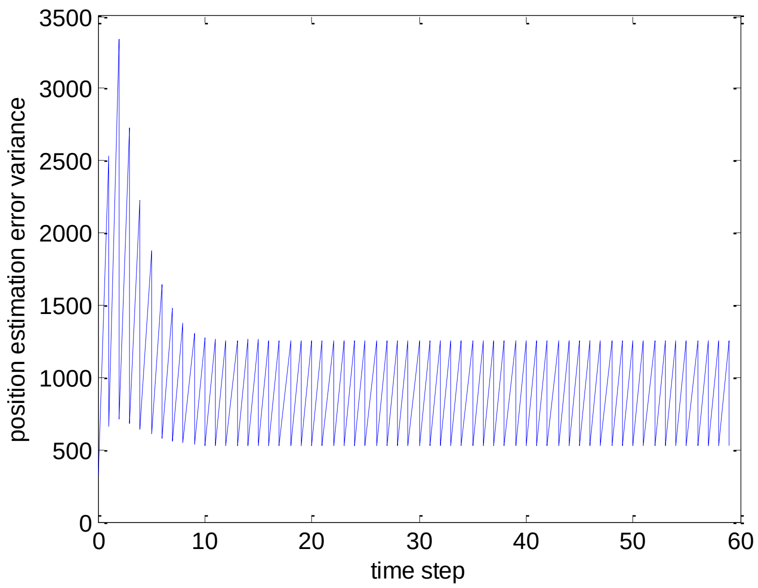


Fig. 5. Sample MATLAB output for the CSU Optimal State Estimation course

Students' participation in research projects and publication with professors. When students conduct research (in the framework of research grants) with professors they can obtain a lot of new knowledge. Many CSU students are currently involved in research on the US NSF projects "Optimal prosthesis design with energy regeneration" ($1.5 million), "The game changer: a new model for password security" ($200,000), Acquisition of a 4G/LTE wireless communications test set" ($252,000), "A spiral computer engineering lab framework" ($245,000), and others. Students are heavily involved in the preparation of articles and papers for the publication of research results [17, 27]. This allows faculty to give students knowledge in modern data information processing and skills in formatting and formulating a goal, introduction, main idea, conclusion, references, citations, and so on.

Gathering students into a single research team. This approach broadens the perspective for knowledge transfer when students with different ICT knowledge can gather in one team for executing one or several projects. For example, students who are members of a research team may have various knowledge in using software for evolutionary optimization (genetic algorithms, partial swarm optimization, multi-objective invasive weed optimization, etc.), decision making based on Pareto optimization, sliding mode control, impedance control, fuzzy logic, artificial neural networks for parametric identification, pattern recognition, image processing, and so on. CSU student teams have the possibility to conduct research in laboratories in the EECS Department such as the Digital Systems Lab, Control Systems Lab, Power Systems Lab, Computer Networks & Distributed Systems Lab, Communications &

Table 1. Relationships between disciplines and software in the EECS Department at CSU

Course Code	Course Title	Software
ESC 120	Introduction to Engineering Design	Arduino (an open-source electronics platform based on easy-to-use hardware and software)
EEC 310	Electric Circuits I	PSpice, MATLAB, MultiSim
EEC 311	Electric Circuits II	
EEC 312	Electric Circuits Laboratory	Agilent IntuiLink software (Agilent scopes and signal generators, breadboards, passive components, transformers)
EEC 315	Electronics Laboratory	
EEC 451	Communications Laboratory	
EEC 314	Electronics II	PSpice, MATLAB/Simulink
EEC 384	Digital Systems Laboratory	EDA (electronic design automation) software from Altera and Xilinx (FPGA prototyping boards, logic analyzers)
EEC 487	Advanced Digital Systems	
EEC 488	Hardware-Software Co-design	
EEC 417	Embedded Systems	Miscellaneous electronics and Software (MPLAB from Microchip)
EEC 421	Software Engineering	Eclipse for Java development
EEC 440	Control Systems	PSpice, MATLAB/Simulink
EEC 450	Communications	SystemView by Elanix (design and simulate communication systems)
EEC 483	Computer Organization	(Microsoft Visual C, Quartus II from Altera (software), DE0 from Altera (hardware)
EEC 492	Software Defined Radio	Universal software (USRP) from Ettus (hardware) and GNU Radio (software), and LabView from National Instruments (software)
EEC 492	Computer Security	Quartus II from Altera (software), DE0 from Altera (hardware)
EEC 525	Data Mining	WEKA, RapidMiner, R (o/s software)
EEC 622	Formal Methods in Software Engineering	Model checker SPIN, Visual Studio
EEC 623	Software Quality Assurance	JUnit, GitHub, SPSS (statistical software)
EEC 624	Software Testing	JUnit (open source testing tools)
EEC 626	Software Engineering Project	Java, Mysql, Perl, Python, PHP, Apache, C#, SQL server, ASP.net, development tools: Eclipse, NetBeans, and, Visual Studio
EEC 683	Computer Networks II	Network simulator NS2
EEC 492/592	Kinect Application Development	Website - http://academic.csuohio.edu/zhao_w/teaching.html
EEC 688/788	Secure and Dependable Computing	
EEC 693	iPhone Application Development	
EEC 693	Network Security and Privacy	Various attack and dense tools

Electronics Lab, Software Engineering Lab, and Senior Design Lab. Available software includes: Altera Quartus II 10.1 SP1, Altera Quartus II 13.1, Cisco Packet Tracer, Oracle VM VirtualBox, Microsoft SQL Server 2008, Microsoft Visual Studio 2010, Microsoft Office 2010, Orcad family Release 9.2 lite Edition, ORCAD 16.5 lite, Python 2.7.5, MATLAB R2013b, dSPACE Control Desk 5.1, ModelSim SE 10.0a, Precision Synthesis 2010 a.218, SystemView V6.0, and Agilent Data Capture Application. BSSU students have the availability of Visual Studio, MS SQL Server, MS Windows Server, MS Windows 7, MS Access, MS Visio, MS Project, Free Ware, Moodle, Libre Office, Eclipse, NetBeans IDE, Ubuntu, FreeBSD, Apache, Qt, OmegaT, VirtualBox, Python, Java, JavaFX, C/C++, PHP, JavaScript, HTML5.

Participation of students in conferences, seminars, and research meetings. The goal of any conference is the sharing of knowledge and discussion of recent research results. CSU hosts a weekly Human Motion and Control seminar that includes senior researchers and students giving presentations (approximately half-and-half) on advanced research results with participation from the departments of EECS, Mechanical Engineering, and Engineering Technology. Moreover, every student has the responsibility to report their research achievements on a weekly basis at meetings or seminars of their separate research team, with additional short presentations on new funding, new methods, software, technology, sensors, computer components, and so on. The Annual Research Day of the WCE (CSU) is a scientific event with poster presentations by master's and PhD students, including time for discussion and awards for the best posters.

Cooperation of the university with advanced ICT companies. This approach allows for the possibility of knowledge transfer within the framework of lectures by ICT company representatives at the university, familiarization by the students with new ICT company software, student internships (NASA Glenn Research Center, General Electric, etc.), joint programming projects, certification of students, and creation of student start-up and spin-off companies [11, 15, 22, 40].

IT for papers, articles, and course work preparation. Students have the possibility to learn specific software editing of their manuscripts using different LaTeX or MS Word templates which correspond to specific journal or conference formatting requirements.

Textbooks and manuals for students based on the recent faculty experience. Courses in the EECS department at CSU are based on the faculty's own textbooks, classical / fundamental textbooks, and internet resources. For example, recent research results on optimal state estimation and evolutionary optimization are represented in faculty textbooks [37, 38] with accompanying MATLAB codes which is available on the CSU website [44].

User-friendly pseudo code in published articles and research projects. At the EECS department, every student has free access to pseudo code. Authors and developers transfer their programming achievements by sharing them with students and the world-wide research community. CSU's web site includes pseudo code which is developed by research teams or individual developers.

Internet search systems and databases. To increase their level of knowledge based from recent research results, students can use search systems from databases such as Scopus, Science Direct, Google Scholar, IEEE Xplore, and others;

Research portals like Research Gate, Linkedln, and others. Students can gain new knowledge by following recent publications from specific authors, by asking and answering questions in dialogues with colleagues, and so on.

Memberships in professional societies. Memberships in professional and scientific societies, like IEEE, IFAC, PBD, and others, gives students a wide spectrum of opportunities for knowledge transfer using the resources of the corresponding society.

6 Evaluation of the Modified University Curricula and Approaches to Knowledge Transfer

An evaluation of the quality of training processes and of the quality of university graduates is a feedback from the implementation of the proposal in Section 4, Research-Based Modification of University Curriculum. Here we propose some indicators for evaluation processes:

a) Awards and participation of students in programming Olympiads, and student research project competitions. For example, a team from CSU's Washkewicz College of Engineering took first place at an international student design competition sponsored by the American Institute of Aeronautics and Astronautics (AIAA). For their winning project they designed, built, and tested an engine air particle separator for an unmanned ariel vehicle using 3D printing technology. BSSU student have been repeated winners in the Aldec, Inc. (USA) Olympiad on C++, VHDL and Verilog [20].

b) The level of published articles by students is indicated by databases such as the Web of Science, Scopus, etc. Other important considerations are the impact factor of corresponding journals, and the rank of conferences with student presentations (international, regional, university, college, department, etc.) [14].

c) Grading of student knowledge and erudition using traditional testing approaches (homework, midterm, term project, final exam) and using advanced software and ICT [9, 36].

d) Tracking graduates and applicants for PhD or DRE programs illustrates research aspirations and the desire for conducting continuing research.

e) Successful employment, for example: (1) CSU graduates work in US companies and industrial corporations such as Rockwell Automation, Phillips, Foundation Software, Winncom Technologies, UTC Aerospace Systems, Swagelok Company, RoviSys, American Railways, United States Postal Service, and others; (2) BSSU graduates work in Canada, France, Germany, Great Britain, Latvia, Netherlands, Norway, Poland, UAE, USA, and Ukraine, including companies such as Camo-IT, Ciklum, eBay, EPAM Systems, GeeksForLess, GlobalLogic, HostingMaks, Linkedln, Luxof, Microsoft Research, MobiDev, NetCracker, Oracle, TemplateMonster, and others.

7 Conclusions

The authors have described research related to the increasing efficiency of university graduate training by modification of the curricula in electrical engineering, and computer science and engineering, based on the latest achievements and advanced research results in the corresponding fields. Analyzing and classifying the knowledge transfer and knowledge evaluation methods for examination and verification of the proposed curriculum modification approach, the authors have presented many educational examples and successful cases from the Department of Electrical Engineering and Computer Science at CSU (USA) and the Department of Intelligent Information Systems at BSSU (Ukraine). Because of the limited space of this paper, only a few specific use cases have been considered. All discussed approaches can be successfully implemented for graduate student curricula modification in other universities around the world, especially those which do not currently use all of the discussed methods.

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