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*Original Paper*

# On the Experience of Joint Mechanical and Electronic Education in the Field of Smart Products and Services Engineering

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***Abstract*** *- One of the main problems of higher education in Serbia is the fragmentation of research and educational entities and their insufficient inter-cooperation where, sometimes, there is no understanding even within the same department when implementing a joint study program. The SPaSE (Smart Products and Services Engineering) module was created as a result of the joint effort of two faculties - mechanical and electronic, where the professors of these two faculties united around a common goal - to try to form an educational content that would be attractive to master's students of both faculty as well as graduate students who have already been employed. The designed module combines the teaching contents of both faculties related to the development of smart products and services, offering currently the most attractive topics within the scope of the Industry 4.0. A framework for cooperation was found in the Jean Monnet Erasmus+ programme, where the European Commission recognized the value of the joint application and offered funding for the pilot project over the previous three years. This paper shows the results of this, for the circumstances of Serbian higher education, very unique cooperation.*

***Key words:*** *engineering education, industry 4.0, smart products and services*

## I. INTRODUCTION

Cyber-physical system represents a complex integrated system that combines physical components with the potentials of computers and networking. It represents the integration of the physical world with the digital world, enabling communication, coordination and cooperation between them [1]. In a cyber-physical system, physical components (machines, devices, sensors, actuators) are connected by software, data and communication networks, achieving real-time monitoring, control and optimization of physical processes using intelligent algorithms and feedback loops. Additional connections of cyber-physical systems with intelligent, internet services - smart services, with appropriate adaptation of characteristics during operation, leads to the smart products [2]. The most advanced smart products today have the ability to diagnose, improve or maintain themselves. They have a very high degree of personalization and can independently cooperate with other smart products [3]. Today, people are more informed about the range of products offered on the market and more demanding when choosing and buying products. They are looking for performance products that will fully meet their specific needs. Because of this, companies are forced to produce personalized product options, available at the request of customers. Industry 4.0 enables individualized or customized flexible mass production based on connecting production processes and services in order to improve quality, reduce costs and increase efficiency. The key is the innovative production, which means that in the fierce market competition, the manufacturer must always find new technical solutions.

The industrial and social transformations dictated by the fourth industrial revolution also define new trends in the education of technical development engineers, where they are expected to be comprehensively educated and trained to work in interdisciplinary project teams, in order to use the acquired knowledge in the field of creative techniques and innovations to create new smart products and services competitive in the market. This kind of education demands expert teachers from various fields. On the other hand, Serbian higher education suffers from high level of fragmentation on different faculties, departments, research groups. Four years ago, a group of professors from two faculties of University of Niš – Faculty of Mechanical Engineering and Faculty of Electronic Engineering decided to make a unique endeavour and to design joint module dedicated to the Smart Products and Services Engineering (SPaSE). First, curricula were designed from ground, based on state-of-the-art contents from the field, then the right teachers were chosen and finances were found through European Commission's Jean Monnet Erasmus+ programme. This paper will present SPaSE module objectives and concept as well as results and experiences after the projects' realization with conclusions and future recommendations.

## II. MODULE OBJECTIVES

The primary aim of the SPaSE module (http://spase.ni.ac.rs/) was to equip master and graduated (with or without employment) students from technical faculties with the necessary competencies to effectively use methods, models, and IT tools for engineering of the new generation of smart products and services with the emphasize on developing their innovation potential and creative techniques. Since product and service development is a critical phase in engineering, it's crucial for development engineers to adopt modern models that lead to creative solutions. The SPaSE module intended to enhance professional competencies and foster innovation in product development, benefiting both educational institutions and businesses in the region.

Another underlying goal of the module was to bridge the noticed gap between existing education model and demands of the modern society. Module had to encourage master students and graduated engineers to think creatively and innovatively through boosting a mind-set that seeks solutions to the real-world problems and identifies opportunities for business improvements in a systematic manner. The term engineering can be defined as the creative application of scientific knowledge and mathematical methods for the development and production of technical products. It is convenient to consider a holistic approach to engineering, where, in addition to the development of products and services, their complete product life cycle is also taken into account. The components of holistic engineering are the models and methods used in the development process, IT tools, information models and organizational structures, united by human resources with appropriate competencies. The key competence of development engineers is creativity, because it enables successful innovations, i.e. the development of creative and market-competitive products.

Gaining adequate knowledge is essential for those who may want to start their own companies or contribute effectively in project management and decision making within the companies they are or will be working for in the future. Courses inside the SPaSE module were conceived in such a manner to lead the students through all the phases of smart product or services development, from idea to the final realization. Students should have gained knowledge not only on product design and I4.0 principles (big data, artificial intelligence, internet of things, digital twins, virtual reality, additive manufacturing, block chain), but also a better understanding of business and legal issues, including market analysis, pitch presentations, finance, marketing, intellectual property, contracts and patents. For the successful development of smart products and services, designers must quickly and flexibly integrate new trends and standards into their solutions. Therefore, the application of efficient engineering of the new generation of smart products and services is necessary. Modern engineering activities are characterized by high interdisciplinarity, networking, complexity and heterogeneity.

## III. MODULE CONTENT

Module „Smart Products and Services Engineering“ was conceived as intensive 15 weak teaching programme. Classes were organized twice a week as four hours teaching blocks. There were 118 school's hours of teaching in total, organized through 11 carefully tailored courses:

C1. Introduction to the European integration and legislation in the field of smart engineering (6 teaching hours) - enhancing understanding of legal, economic, political, and social aspects of European integration and its benefits with emphasize on the industry 4.0

C2. Industry 4.0: Smart products and services engineering (12 teaching hours) – gaining the knowledge and skills for the efficient application of engineering of the new generation of smart products and services

C3. Creativity and innovation in product development (12 teaching hours) - mastering creative skills and competencies as well as innovative techniques helpful in developing of smart products and services

C4. Digital product development (12 teaching hours) - using state of the art technologies and methods in the process of development of digital products

C5. 3D CAD construction (10 teaching hours) - getting the knowledge about the basic objects and their relative positions and sections, developing surfaces, as well as the vector analysis and computing graphics

C6. Information technology (12 teaching hours) - introduction to the basic IT principles, methods, and techniques necessary for all stages during the development of hardware and software solutions

C7. Artificial intelligence (12 teaching hours) - introducing the concepts and algorithms at the foundation of modern artificial intelligence, and exploring the ideas that gave rise to smart products and services

C8. Big data and data analytics (12 teaching hours) – familiarizing with the principles of Big data and data analytics, gaining understanding of the basic tools and techniques for data collection, processing and analysis

C9. Internet and sensing technology (12 teaching hours) - providing an overview of technologies focusing on the Internet of Things and Industrial Internet of Things

C10. Digital twins (10 teaching hours) – introduction to the virtual representation of an object or system during its lifecycle, which is updated from real-time data and uses simulation, machine learning, and reasoning to help decision-making

C11. Business models I4.0 (8 teaching hours) - providing an in-depth perspective of companies' processes, structures, and tools necessary for business model innovation in the scope of the industry 4.0

The crown of the students' three months efforts was to publicly present business models of their original innovative solutions for new smart products or services in the

form of pitch presentations. Students developed their ideas inside the teams (2-3 students) with supervision from Module teachers. Throughout that process, students developed communication and teamwork skills essential for fostering a collaborative work environment and successful project realization. They also had the opportunity to develop other competencies and skills needed for successful entrepreneurship, like spotting opportunities, decision-making, motivation, critical thinking, problem-solving, and planning and management. In addition, students visited successful business entities in the region inside the Science Technology Park Niš and got familiar with some examples of good practices in the engineering entrepreneurship.

Students' business plans had to contain technical details but also various business and legal issues, including market analysis, financing and marketing plans, intellectual property and patent search. Some students also seized the opportunity to work and develop prototypes of their products on modern laboratory software and equipment like 3D printers, CAD software, VR development studio.

## IV. FINANCING AND REALIZATION

At the very beginning, it was obvious that a study program conceived like this, had to be implemented with the joint involvement of university professors of different scientific background, mainly from mechanical and electronic proficiency. First step was to form a team of established teachers from various scientific areas who designed adequate contents from their area of expertise. These professors had to work together to make courses which can interact, and that was the most challenging effort. When the content of the module was designed in most important features, module team looked for institutional support for the module realization. We found the necessary understanding for the module realization from the University of Niš management and finances from the European Commission, under the Jean Monnet Programme.

The Jean Monnet Programme is an essential initiative under the Erasmus+ programme, launched by the European Union (EU) to enhance the quality of teaching, research, and dialogue in the field of European Union studies. The programme is an important tool in the EU's educational and cultural diplomacy, offering opportunities to academics, students, and institutions across the globe to engage in EU-related academic activities. Main objectives of the programme are to promote teaching and innovative research, to foster dialogue between academia and policy-makers and to support networking and cooperation among scholars, institutions, and researchers. One of the tools in supporting these objectives is financing of Jean Monnet Modules - short courses or teaching programs that focus on specific topics related by the development goals the European Union.

SPaSE team succeeded with the Jean Monnet application and began with the SPaSE (Smart Products and Services Engineering) project realization at the end of 2021 under the grant number 101047566-JMO-2021-HEI-TCH-RSCH. Project was financed with 30.000 euros and its duration was 36 months (December 2021 – November 2024). During these three years, University of Niš obliged to have free of charge courses each year to all interested master or graduared students (20 students was a minimum). To that purpose, University of Niš had open calls for enrolment and promotions on social networks and in local and national media. For instance, call for the first generation of students published in the oldest Serbian newspaper "Politika" is shown in the Fig. 1 .


Fig. 1. SPaSE promotion in newspaper "Politika".

Besides courses, SPaSE team obliged to numerous accompanying contents with also great importance like reaching interested stakeholders (academia, local government and business entities), having round tables, study visits, workshops. Important goals were also writing the Handbook on Smart Products and Services and several scientific papers on that topic.

## V. RESULTS AND EXPERIENCES

Project realization was successful. Three generations of students participated in the project with great interest for module courses. Covid 19 was still relevant at the beginning of the project, so we had to adjust to the current situation with having part of our courses online in the first year of the project. Also, many students were already working, so we had to adjust our working hours with their schedule, so we usually worked on two blocks a week - Wednesdays afternoon and Saturdays. Students had the opportunity to hear many state-of-the-art topics, to work on modern equipment, to visit Science Technology Park Niš and some successful companies in domain of smart products and services (Figures 2 and 3). Teaching materials and approach to the students changed during the project realization based on students' feedback and quality control forms, each year.

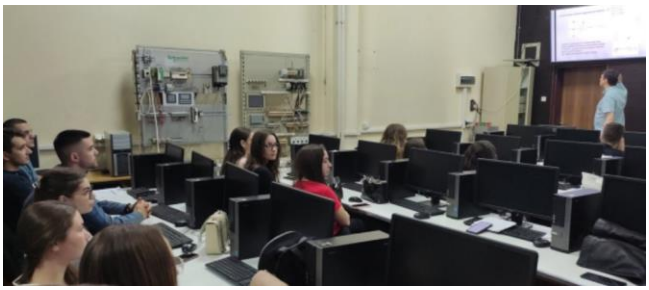

Fig. 2. Classroom work.

Fig. 3. Study visit.

One important aspect of the project realization was having round tables on different topics as well as guest lecturers for each generation of students. Round tables were the great opportunity to discuss important questions with other professors, business representatives and our students. For instance, some of the topics for discussion were: "EU practice in engineering of smart products and services", "Is Artificial Intelligence Changing the Engineering of Smart Products and Services?", "How the smart products and services impact the everyday life?".

As already stated, at the end of the module, students had to publicly present business models of their original innovative solutions for new smart products or services in the form of pitch presentations in front of the module teachers and other colleagues. Their products were mostly very creative and well elaborated, with some amazing ideas like:

- Smart dog feeder with AI implemented breed recognition, health risks assessment, communication with the owner
- Smart football referee with integrated ball tracking, hawk eye system, AI implemented offside, yellow and red card issuing
- Smart personal wardrobes with adequate clothing recommendations based on personal habits, daily routines, outside weather
- Smart trash cans, beehives, natural gas cylinders

Unfortunately, not all the enrolled students finished the module. Some students gave up because they didn't manage to harmonize heavy tempo of the module realization with their jobs or other obligations, and, some didn't manage to pass the final exam or they didn't do their projects assignments in satisfactory manner. In the first year, 25 students out of starting 33 earned certificates for module attendance, 26 out of 31 the second year (Fig. 4), and 24 out of 30 the third year.

The three-year experience of holding the module is summarized in the Handbook on Smart Products and Services [4]. The Handbook consists of introductory considerations and four thematic chapters. The first chapter *Industry 4.0* gives an overview of the historical epochs of industrial development, concluding with the emergence of Industry 4.0 and smart products and services as its outcomes. It is followed by the chapter *Smart product development models*, which describes the stages of the process of creating smart products as well as the main state of the art models of their development and construction. This is followed by the chapter *IT tools for the development of smart products and services*, which, after an introduction on information technologies, deals in more detail with specific tools for the development of smart products and services (artificial intelligence, big data and data analytics, internet and sensor technologies, and simulation and digital twins). The final chapter of the Handbook *Defining an efficient procedure for the development of a new generation of smart products and services* is devoted to a holistic approach to the development of smart products based on the new V-model of engineering.

Fig. 4. Certificates awarding for the second generation of students 2023.

The Handbook can also find its future application outside the SPaSE module. It can be useful for the education of students of technical faculties for the acquisition of professional competences and innovative readiness in the field of product development, as well as for development engineers in the industry for the design of smart, market competitive, products and services. The manual also aims to provide decision-makers with guidelines for the effective development of smart products and services, as well as to guide any organization that wants to develop its capacity to implement adequate policies.

Results of the project were also sporadically published in scientific journals and conferences. In the work [5] "Sys-

tematic approach to the education in the field of smart products and services engineering", authors have presented the development of education through the epochs of industrial development and trends and challenges related to the education 4.0. Special attention was paid to the education of development engineers and the relevant competencies they need to have in order to meet the tasks and expectations in modern conditions. Paper [6] "Implementation of the New Curricula in Smart Products and Services Engineering" presented main aspects of newly designed module "Smart Products and Services Engineering" as well as its aspiration and goals. Finally, work [7] "Role and Importance of Digital Technologies in the Development of Smart Products" demonstrated the role and importance of digital technologies in the development of smart products, as well as their application in separate stages of product development. The paper presented a V-model for the development of smart products, which has a holistic approach and is based on the principle of interdisciplinary system architecture, which enables the synchronized development of mechanical, electronic and software components with appropriate integration, validation and verification.

Fig. 5. Project's board meeting.

## VI. CONCLUSIONS

The SPaSE module aimed to equip students with essential skills in smart product and service engineering, fostering creativity and innovation while bridging the gap between academic education and industry demands. By covering a wide array of topics—ranging from Industry 4.0 principles and AI to legal and business aspects—the module prepared students for real-world challenges and entrepreneurial ventures. The initiative successfully cultivated professional competencies and produced impactful results, demonstrating the importance of interdisciplinary education.

The project's scriptures, encapsulated in the SPaSE handbook, promise to benefit future engineers and industry professionals alike. All the professors from the module benefited greatly from these three years and new teaching content is already part of their everyday teaching at their native faculties. SPaSE team tried this year again to get the Jean Monnet project with the continuation of our idea, this time deeper in the field of engineering entrepreneurship, but we failed, although being close to get financing. There is no doubt that we will try again next year with this or some other program, because SPaSE experience of joint mechanical and electronic education was very fruitful for all of us. Also, maybe we should think about possibilities of, for instance, making joint master study programme on Smart Products and Services Engineering located and accredited at the University of Niš, where the Faculties of Civil Engineering and Technology would be also involved in the implementation.

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