SUSTAINABLE DEVELOPMENT AS A CHALLENGE OF ENGINEERING EDUCATION

by

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The purpose of this paper is to research the ways of integrating sustainable development into study programs of engineering faculties in an international context, as well as to analyse the current state of engineering education for sustainable development at the universities of the Republic of Serbia. Therefore, a desktop research, as well as an analysis of the engineering education curricula, have been conducted. The results of the research indicated to two possible approaches to the integration of sustainable development into the engineering curricula – in the form of special subjects dedicated to the problems of sustainable development in the engineering, or as an integrative approach which implies that sustainable development becomes an integral part of the entire curriculum. Subjects dedicated to sustainable development have been identified at all universities, but not at all faculties where engineers are educated in the Republic of Serbia, they are present at all levels of study (undergraduate, master, doctoral), as well as within applied, integrated and specialist studies, and by status they are most often elective. The results confirm that the engineering curricula open up towards the questions of sustainable development both in international context, and in higher education of the Republic of Serbia and as such, they can serve to the relevant ministries of education and science, universities and engineering faculties as a recommendation in which way to plan and design higher education of engineers in the future in order to provide overall support in the integration of sustainability into the engineering.

Key words*: engineers, education for sustainable development, curriculum*

Introduction

In the second half of the last century, especially after the Bruntland Report and Agenda 21 (Rio de Janeiro 1992), technical faculties intensified the implementation of environmental issues in the curricula, especially in the field of civil engineering, architecture and chemical engineering. In addition, engineering networks and initiatives dedicated to the environmental education of engineers were established, and issues related to environmental engi-

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neering were discussed at a series of conferences. At the beginning of the 21st century, the environmental education of engineers got expanded to the issues of education for sustainable development. At the first conference on the education for sustainable development of engineers (held in 2002) it was emphasized that the education of engineers can contribute to sustainable development, *i.e*. that the education of engineers should be adapted to the requirements of sustainable development [1]. In other words, this conference indicated that the engineers are necessary for sustainable development and that this requires some changes in their education in a sense that their education should be based on learning how to think long-term in order to focus engineering activities on long-term sustainable solutions [2].

The education for sustainable development of engineers should contribute to their understanding of the sustainable development issues and raise their awareness about the ways in which their actions and behaviours can become sustainable [3]. The importance of this education is reflected in the connections between the engineering and the dimensions of sustainable development: the engineering requires resources to drive much if not most of the economic activities in almost all economic sectors – industry, transportation, residential, commercial, *etc*. (*economic dimension*); the resources used in engineering (minerals, fuels, water, *etc*.) come from the environment, and the waste generated as a product of engineering processes (such as production, transport, storage, utilization, *etc*.) is usually released into the environment (*environmental dimension*); the engineering services enable a good living standard and often support the social stability as well as the cultural and social development (*social dimension*) [4]. Numerous solutions of the global issues require engineers to create and construct the ecological and socially just systems within the limits of nature's sustainability, without compromising the future generations. At the same time, as governments move towards the policies that promote the international marketplace, the students must be prepared to succeed in the global economy. The young workforce will play a critical role in eradicating poverty and hunger, enabling sustainable development, developing appropriate technology and useful infrastructure, and in promoting environmentally and socially just change [5].

Methodology

Starting from the need and the importance of the education for sustainable development of engineers, the course of the research is the integration of sustainable development into the curricula of engineering education, both internationally and in the Republic of Serbia. Accordingly, two research tasks were defined: to investigate the ways of integrating sustainable development in the foreign engineering higher education institutions and universities' curricula and to investigate the current situation of the education for sustainable development of engineers in the Republic of Serbia.

The first research task (international context) was conducted by reviewing the literature. The following keywords were used to search through the Google Scholar and KoBSON databases: *engineering education for sustainable development, curriculum and sustainable development integration, sustainable engineering,* and *sustainable universities*. The selection of the literature sources led to the references used in the paper. The analysis of these sources resulted in identifying the basic ways of integrating sustainable development in the curricula of engineering education, as well as the authors' views on the problems and the difficulties that accompany this integration. In addition, this paper points to the examples that illustrate the ways of integrating sustainability into the curricula of engineering education at some universities.

The realization of the second research task (national context) consisted of two parts. First, an analysis of the engineering education curricula in the Republic of Serbia was con-

ducted in order to identify the courses dedicated to sustainable development. The focus was on those courses whose names contain the terms *sustainable* or *sustainability*. The courses that are dedicated to only one of the dimensions of sustainable development were excluded from the analysis (most often these are courses related to the mentioned environmental education of engineers). Subsequently, the syllabi of the courses available on the official faculties' websites were collected, in order to determine: the representation of the courses at the different levels of study; the representation of the courses at the different years of studies; the status of the course, *i.e*. whether the course is compulsory or elective; and the representation of the course at the different fields of engineering.

The research sample consisted of all engineering education study programs within five universities of the Republic of Serbia: the University of Novi Sad, the University of Belgrade, the University of Kragujevac, the University of Nis, and the University of Pristina.

The ways of integrating sustainable development in the engineering education curricula in the international context

In general, there are two ways of integrating sustainability into the curricula, which also refers to the education of engineers. The first way involves adding one or two courses dedicated to sustainability or environmental technologies without disrupting the existing program [6]. The authors [1, 7] characterized such approaches to the integration of sustainability into the education of engineers (additional courses, teaching other teachers about sustainable development, and creating a track for sustainable development specialists) as *naive*, stating that this type of integration is, at best, only the initial step.

Sanchez-Carracedo *et al*. [7] emphasize that the next steps should *not only address what course should be added to make engineering more sustainable but also the question of what type of curriculum might contribute effectively to sustainable development*. This is the second way of integrating the sustainable development into the education of engineers, which implies that sustainability should become an integral part of the entire curriculum, including as many teachers as possible. Despite the fact that many authors show a preference for this way of integration, it requires great institutional changes, changes in culture, the support of scientists, lecturers and the university board, which is why the university practice is usually to use the first way of integration.

Mesa *et al*. [8] suggest that the rigorous academic plans for engineering education leave no room for additional courses, while Lourdel *et al*. [9] point out that the very complexity of sustainable development also supports the claim that it cannot be integrated into the engineering education just as an additional course. Sustainable development represents a new integrative principle, not a new set of tools, so the concept of sustainable development cannot be regarded as only an *addition* to the existing skills and educational programs of engineers [10]. Thus, a course dedicated to sustainable development is not sufficient [11], but sustainability needs to be *intertwined* with the existing courses [8].

Mulder [11] points out that many faculties show interest and agreement when it comes to the goals of integrating sustainable development into the curricula, *but do not know to achieve it*. Huntzinger *et al*. [12] believe that it is necessary to start from overcoming the resistance to change that characterizes entire universities, departments, members of the academic community and students. One of the examples of such cases is the resistance shown by the lecturers. Quist *et al*. [6, p. 869] emphasize that *a shift towards sustainability in engineering education should include substantial learning by lecturers, especially on the level of paradigms and mental frameworks, before they will really be fully capable of integrating sus-*

tainability in their teaching. However, many teachers show resistance when it comes to such change. Also, even if teachers do show desire to make this shift, they often lack knowledge and know-how [6].

The graduates often *lack understanding of environmental, social and economic impact, are insensitive to cultural idiosyncrasies and are not cognisant of human-centred design practice* [13]. Another problem is that they also lack advanced skills in the field of critical thinking, gathering, evaluating and applying information, as well as the experience of dealing with uncertainty and ambiguity in problem-solving. The focus is instead on memorizing the facts and the established procedures. As a result, the engineers enter the labour market *poorly equipped* to deal with the problems of modern society [12].

In the report *Engineering: Issues Challenges and Opportunities for Development*, published by UNESCO in 2010, it is stated that: *this is at a time when there is an urgent need for engineers to develop the technologies that will be essential in the next wave of innovation based on environmentally sustainable "green" engineering and technology that we will need if we are to address climate change mitigation and adaptation – if we are to save spaceship Earth* [14, p. 17]. As Vehmaa *et al*. [15] emphasize, the engineering shapes our society in different ways, therefore enabling the social and economic development through technology and innovation. Engineering activities directly affect people's lives and nature. However, most people, including engineers themselves, are not aware of this impact [16].

There is no doubt that sustainable development represents a great challenge for the 21st century engineers [11], and that engineer education is the key to sustainability [15]. Al-Rawahy [17] gives a proposition of the model of such education through several conclusions. First, it is necessary for engineers to acquire knowledge about the basic issues of sustainability and development, such as issues of industrial and economic development, environmental impacts, globalization, population growth, social, cultural, political, ethical and moral aspects of development, global crisis, *etc*. Then, it is important to change the way an engineer thinks, makes decisions and interacts with people. This must be based on the ethical and moral values, transparency and pursuit of truth. The engineers must be educated about the problems of the modern way of life, such as the consumerism and life-cycle concept. Therefore, it is necessary to integrate these aspects into the curriculum as well. The author also proposes a special course *Energy: sources, availability, use, efficiency, conservation, and environmental impacts* as necessary for any engineering discipline. In the end, every engineer should develop communication skills and get to know the habits, norms, values and traditions of different cultures, given the accelerated development of technology, the changing patterns of production and trade, the increased mobility, *etc*. In addition, the traits such as creativity, innovation, entrepreneurship, honesty, vision, *etc*. are also important for achieving competitiveness [17].

Starting from the issues raised by Agenda 21, Chapter 35 [18] and Chapter 36 [19], the UNESCO Engineering Initiative [20] and the Sustainable Engineering Initiative [21], many engineering faculties have become pioneers in incorporating sustainable development and sustainable science into their curricula [22-24]. This is evidenced by the efforts of many faculties, such as Chalmers University of Technology (Sweden), Tecnológico de Monterrey (Mexico), Technical University of Catalonia (Spain), TU Delft (Netherlands), ETH Zurich (Switzerland) and others. Ways of integrating sustainability into engineering curricula are manifested as follows, tab 1.

However, the research on the concept of sustainable development from the perspective of engineering students [25] and on the understanding of sustainable development from the perspective of the students from other faculties [26] show that their knowledge and under

Table 1. The ways of integrating sustainability into engineering curricula – examples of good practice

California Polytechnic State University (California)	As a part of the electrical engineering laboratory courses, the students are required to fill out a special section on sustainable development when submitting their weekly reports on the conducted experiments: how experiment topics, or applications related to the experiment, foster or prevent sustainability. The analysis is focused on linking the energy and the resource use with the environmental, social, economic and political aspects of sustainable development [27].
Chalmers University of Technology (Sweden)	Sustainable development is actively promoted in Bachelor and Master programs in accordance with the adopted vision *Chalmers for a sustainable future*. There is no single program specifically dedicated to sustainable development, but the idea is to integrate sustainable development into all programs [28]. A project focused on the education for sustainable development (2006-2009) was also implemented with the aim of improving the quality of courses dedicated to sustainable development and the quality of the content on sustainable development in other courses [29].
Delft University of Technology (Netherlands)	Sustainable development is achieved through three operations: the basic course *Technology in sustainable development* for all students, consisting of a general part that includes the basic concepts, models and practical exercises and a special part where sustainable development is associated with a specific discipline; the integration of sustainable development into all regular disciplinary courses, in accordance with the nature of each course; and the possibility to graduate in a sustainable development specialization within each department [3, 11].
Rowan University (New Jersey)	Sustainable development is a part of a joint course *Engineering clinic* focused on the engineering design with a special emphasis on understanding the relationship between the environment, pollution prevention, ethics and laws and the engineering design. It is studied during eight semesters: life cycle analysis, use of green materials (I, II); alternative energy sources, sustainable development (III, IV); projects in which students design the products suggested by industry, government, companies, **etc**. with respect to the environmental aspects (V-VIII) [30].
Swiburne University of Technology (Australia)	There is a course dedicated to the product design (the Product Design Engineering Program) whose goal is for students to gain an understanding of the role of engineers in the society through a continuous exposure to the real world learning opportunities. The emphasis is on project learning, where the students often cooperate with the humanitarian and other organizations in order to address real world scenarios [13].
Universidad Politecnica de Catalunya (Spain)	Greening the curriculum of all courses is achieved through manuals for students and teachers and a special *school curriculum greening plan* created in co-operation with the teachers, professional organizations and former students. In addition, a *department greening plan* which is oriented towards the research activities and the department life, besides the curriculum, has been designed. A platform for the exchange of information the Virtual Resources Center on Curriculum Greening in Technology and the elective course *Environment and technology: environmental education in engineering* have also been created [11].
Engineering sustainable solutions program (Australia)	The aim of the project is to integrate key information, *i.e*. the *critical literacy* items relating to sustainability into the engineering curricula. The program consists of several modules. Each module contains six separate *technical units* (*e.g*. the role of engineers in sustainability; engineering and poverty reduction; nature-inspired design, *etc*.) that can be presented through full-day workshops, lectures or as part of a broader course/program [31].

standing of sustainable development is not at a satisfactory level. There are gaps in their knowledge when it comes to the economic and social dimensions of sustainable development, while the situation is better when it comes to the dimension of environmental protection. Considering the fact that the engineering profession has a wide range of environmental impacts (industry, wastewater, transport, *etc*.), it can be concluded that the environmental education of

engineers is certainly necessary, but not sufficient. The 21st century engineers must develop a holistic approach to the social, economic and environmental problems in the environment, *i.e.* they must develop such professional actions and behaviours that are in line with the concept and the strategy of the future sustainable development [32].

The integration of sustainable development into the engineering education curricula in the Republic of Serbia

Starting from the identified needs and the importance of integrating sustainable development into the engineering education curricula, the authors focused on the investigation of the current state of the education for sustainable development of engineers in the Republic of Serbia. The main objective was to identify special courses dedicated to sustainable development. A total of 80 courses were identified. They are presented in tab. 2.

Table 2. The courses on sustainable development at the faculties of engineering education in Serbia

University of Kragujevac	**Faculty of Mechanical and Civil Engineering in Kraljevo**[1] Sustainable use of natural resources and environmental protection system (UAS)	
	Faculty of Engineering, University of Kragujevac[2] Sustainable development of motor vehicles (UAS) Principles of sustainable development of urban and rural areas (UAS)	Sustainable development and circular economy (MAS) Sustainable development in urban areas (MAS)
	Faculty of Agronomy in Čačak[3] /	
	Faculty of Technical Sciences, Čačak[4] /	
University of Novi Sad	**Faculty of Civil Engineering, Subotica**[5] Energetically sustainable architecture (UAS)	Sustainability of urban space (MAS)
	Technical faculty "Mihajlo Pupin", Zrenjanin[6] Sustainable development (UAS) Sustainable use of natural resources and environmental protection system (UAS)	Sustainable development (MAS) Information and technological support for sustainable biosystem development (MAS) Sustainable agriculture engineering (MAS)
	Faculty of Technology, Novi Sad[7] Sustainable development and industrial systems (UAS) Sustainable development and energy (MAS)	Engineering principles of sustainable water and energy management (MAS)
	Faculty of Technical Sciences[8] Sustainable use of natural resources and environmental protection system (UAS) Planning and sustainable development of landscapes (UAS) Risk management and sustainable development of settlements (UAS) European integration strategies and sustainable development (BAS) Modern approaches to engineering for sustainable biosystems (SAS) Sustainable agriculture engineering (MAS) Planning and sustainable development of landscapes (MAS) Sustainable production (MAS)	Sustainable regional development and EU strategies (MAS) Information and technological support for sustainable biosystem development (MAS) Procedures and machines for sustainable agriculture (DAS) Sustainable logistics (DAS) Sustainable design and safety of products (DAS) Sustainable urban transport systems (DAS) Design of roads from the aspect of sustainable safety (DAS) Modern approaches to engineering for sustainable biosystems (DAS)
	Faculty of Agriculture[9] Environment and sustainable development (UAS)	Sustainable agriculture (MAS) Sustainable environmental management (MAS)

[1]www.mfkv.kg.ac.rs, [2]www.fink.rs, [3]www.afc.kg.ac.rs, [4]http://www.ftn.kg.ac.rs/, [5]http://www.gf.uns.ac.rs/, [6]http://www.tfzr.uns.ac.rs/, [7]www.tf.uns.as.rs, [8]www.ftn.uns.ac.rs, [9]http://polj.uns.as.rs

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Table 2. Continuation

University of Belgrade	**Faculty of Architecture**[10] Sustainable urban communities (UAS) Sustainable urban communities –project (UAS) Sustainable architecture - principles of designing green and energy efficient buildings (SAS) Thermotechnical systems and sustainable architecture (SAS) Sustainable urban development (SAS) Theoretical foundations of sustainable development (IAS)	Theoretical foundations of sustainable development (MAS) Architects and civic initiatives for sustainable development (MAS) Renovation of buildings in the context of sustainable architecture (MAS) Cognitive processes of urban planning of sustainable development (DAS)
	Faculty of Civil Engineering[11] Risks and sustainability in construction (SAS)	Sustainable solid waste management (SAS)
	Faculty of Mechanical Engineering[12] Combustion and sustainable development (UAS)	Ecodesign and sustainable logistics (DAS)
	Faculty of Mining and Geology[13] Mineral raw materials, society and sustainable development (UAS) Energy and sustainable development (MAS) Sustainable development and mineral resources (MAS)	Special chapters on the intervention and sustainable use of mineral waters and geothermal energy (DAS) Special chapters on the intervention and sustainable use of low-mineralized waters (DAS)
	Faculty of Transport and Traffic Engineering[14] Sustainable development of air transport (UAS) Policy and economics of sustainable transport development (UAS)	Strategies for sustainable road transport of goods (UAS) Transport policy within the sustainable development strategy (DAS)
	Faculty of Agriculture[15] Sustainable management of natural resources of the Republic of Serbia (MAS)	Principles of sustainable management of natural resources (MAS) Sustainable management of natural resources and the environment (DAS)
	Technical Faculty in Bor[16] Technologies and sustainable development (UAS)	
	Faculty of Technology and Metallurgy[17] Sustainable development (UAS)	
	Faculty of Forestry[18] Policy and management of sustainable land development (MAS)	
	School of Electrical Engineering[19] /	
University of Nis	**Faculty of Electronic Engineering**[20] Engineering education and sustainable development (UAS)	
	Faculty of Mechanical Engineering[21] Environmental protection and sustainable development (UAS)	Selected chapters from the theory of sustainable development (DAS)
	Faculty of Technology in Leskovac[22] Principles of sustainable development (MAS)	Sustainable development and renewable energy sources (MAS)
	Faculty of Occupational Safety[23] Sustainable development (UAS)	Local sustainable development (MAS) Sustainable housing (MAS)
	Faculty of Agriculture in Kruševac[24] Organization and sustainability of agricultural production (UAS)	
	Faculty of Civil Engineering and Architecture[25] /	

[10]http://www.arh.bg.ac.rs/, [11]www.grf.bg.ac.rs/home, [12]www.mas.bg.ac.rs, [13]www.rgf.bg.ac.rs, [14]https://www.sf.bg.ac.rs/index.php/sr-rs/, [15]http://www.agrif.bg.ac.rs/, [16]https://www.tfbor.bg.ac.rs/, [17]www.tmf.bg.ac.rs, [18]www.sfb.bg.ac.rs, [19]www.etf.bg.ac.rs, [20]www.elfak.ni.ac.rs/rs, [21]www.masfak.ni.ac.rs, [22]www.tf.ni.ac.rs, [23]www.znrfak.ni.ac.rs, [24]https://poljfak.ni.ac.rs, [25]www.gaf.ni.ac.rs

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Table 2. Continuation

University of Pristina	**Faculty of Technical Sciences**[26] Sustainable development (UAS) Sustainable use of natural resources (UAS) Sustainability, resilience and built environment (SAS) Sustainability and resilience assessments (SAS)	Management in the context of sustainability and resilience (SAS) Risk and sustainability management in construction (MAS) Environmental economics and sustainable development (DAS)

[26]http://ftnkm.rs/

Notes. UAS – undergraduate academic studies; MAS – master academic studies; DAS – doctoral academic studies; SAS – specialist academic studies; BAS – basic applied studies; IAS – integrated academic studies

Based on the data from tab. 2, it can be concluded that the University of Novi Sad offers the largest number of courses dedicated to sustainable development and that most of them are represented at the Faculty of Technical Sciences. This faculty has a large number of departments in the field of engineering (environmental engineering, architecture, industrial engineering, mechanical engineering, traffic, *etc*.). Therefore, it is quite understandable (and certainly positive) that a large number of courses is dedicated to sustainable development.

Table 2 also shows that the courses on sustainable development are present at every level of study (undergraduate, master, doctoral), as well as within specialist, applied and integrated studies. The representation of courses by the level of studies is presented in fig. 1.

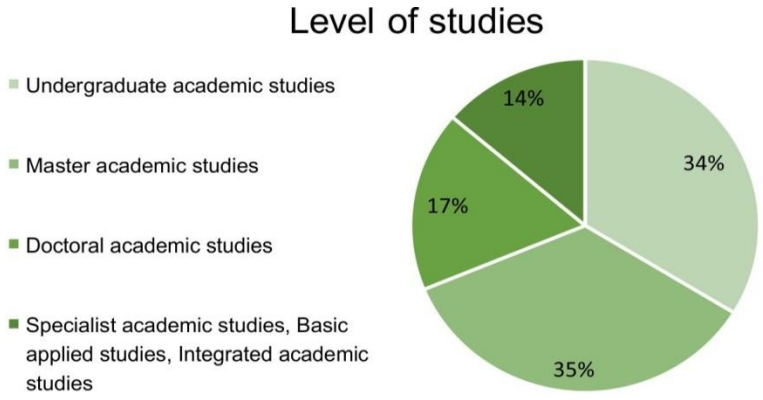

Figure 1. The representation of courses according to the level of studies

The number of courses on sustainable development at master academic studies, that is 28 courses (35%), and undergraduate academic studies that is 27 courses (34%) is almost equal. When it comes to doctoral academic studies, 14 (17%) courses were identified, while the courses dedicated to sustainable development within specialist academic studies, basic applied studies and integrated academic studies were classified in the same category. There are 11 such cases (14%).

The representation of courses on sustainable development by year of studies is presented in fig. 2.

As fig. 2 shows, when it comes to the year of studies, the courses are divided into the following categories: first year of undergraduate studies (3 courses), second year of un-

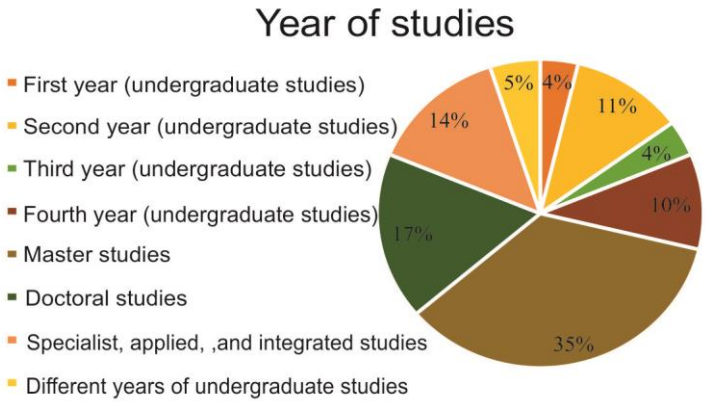

Figure 2. The representation of courses on sustainable development by year of studies

dergraduate studies (9 courses), third year of undergraduate studies (3 courses), fourth year of undergraduate studies (8 courses), master studies (28 courses), doctoral studies (14 courses), while the courses studied within the specialist, applied and integrated studies are classified in the same category (11 courses). A special category was made for those courses that are studied at the same faculties in different years of undergraduate academic studies (same course/same faculty/different years of undergraduate academic studies). There are 4 such courses (*e.g.* the course Sustainable use of natural resources and environmental protection system (Faculty of Technical Sciences in Novi Sad) is studied in the second year in the departments Architecture and Environmental Engineering, while in the Geodesy and Geomatics department, this course is studied in the third year).

Figure 3 shows the representation of courses on sustainable development by their status (compulsory or elective).

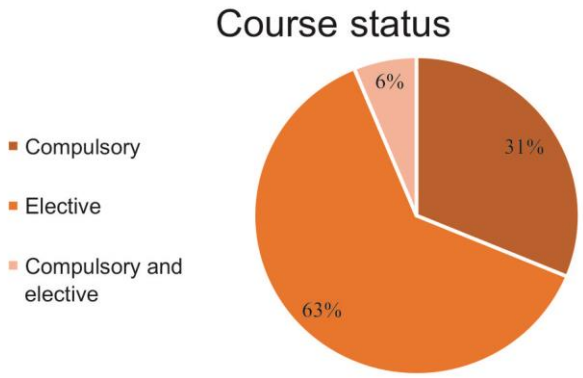

Figure 3. The representation of courses on sustainable development by their status

Courses dedicated to sustainable development are mostly elective and there are 50 such courses (63%), while 25 courses (31%) are compulsory. In addition, a special category which includes those courses that have different status in different departments/years of stud-

ies has been formed. It includes 5 courses. For example, the aforementioned course *Sustainable use of natural resources and environmental protection system* is compulsory in Architecture and Environmental Engineering departments, while in the Geodesy and Geomatics department this course is elective.

The courses are also classified by the fields of engineering, fig. 4.

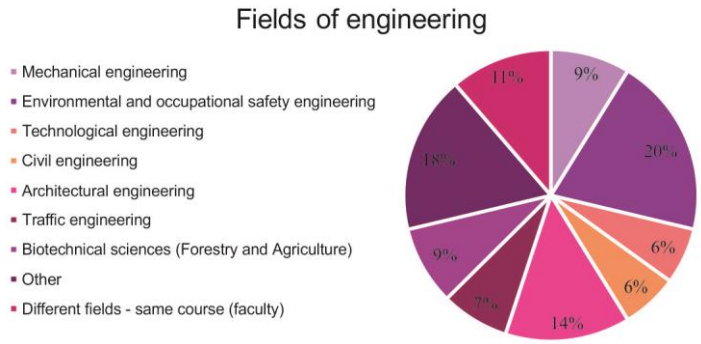

Figure 4. The representation of courses on sustainable development by the field of engineering

Considering the professions referred to as *engineering* [33] and the data available on the websites of the faculties, the fields of engineering are divided into: mechanical engineering, environmental and occupational safety engineering, technological engineering, civil engineering, architectural engineering, traffic engineering, biotechnical sciences (forestry and agriculture) and the category named *other*, intended for those fields where the courses on sustainable development are less represented. In addition, a special category for the same courses that are studied in different fields of engineering at one faculty has been formed.

The largest number of courses belongs to the environmental and occupational safety engineering, specifically 16 courses (20%), which is followed by the architectural engineering courses (11 courses). The category *other* includes 14 courses (18%) that belong to the fields in which the courses are the least represented: electrical and computer engineering, industrial engineering and engineering management, urbanism and regional development, mining, geology, textiles and design. A special category includes 9 courses (*e.g.* the course *Sustainable Development* is at the Faculty of Mining and Geology in Belgrade studied in different departments: Mining engineering, Environmental engineering and Oil and gas engineering).

Conclusions

The role of the engineering education in achieving the sustainable development goals is promoted both in academic discourse and at the policy level, especially since the Rio Conference (1992) and Agenda 21, through the Millennium Development Goals (2000), The United Nations Decade of Education for Sustainable Development (2005-2014), to Agenda 2030 and other documents and initiatives by engineering networks and associations. The integration of sustainability into the engineering curricula is recognized as a key factor for developing the competencies of future engineers that will help them make sustainable solutions and use resources in a way that does not endanger the environment, but actually preserves and protects it for the future generations.

In the international context, progress has been made when it comes to the initiatives to integrate sustainable development into the curricula of technical faculties. The analysis of the integration of sustainability into the engineering curricula has showed that:

- There are two basic ways of integrating sustainable development into the curriculum: the first implies designing special courses dedicated to sustainable development, while the second way represents an integrative approach that implies that sustainability should become an integral part of the entire curriculum.
- The major difficulties that arise when integrating sustainable development into the curricula are related to: lack of space for new courses in the curricula; complexity of the issues and the concept of sustainable development; insufficient knowledge and skills of the teaching staff, and resistance to change.
- The importance of integrating sustainable development into the curricula of the engineering education is reflected in the need to raise students' awareness of the impact of their future profession in the context of the dimensions of sustainable development (society, economy and environment), and especially when it comes to their responsibility for the use of materials, energy use, product design, *etc*.

The analysis of the integration of sustainability in the national context, that is the integration of sustainability into the engineering curricula of the universities in the Republic of Serbia, showed that:

- Courses dedicated to sustainable development were identified at all analysed universities (University of Kragujevac, University of Novi Sad, University of Belgrade, University of Nis and University of Pristina), but not at all engineering faculties.
- There are courses on sustainable development at every level of studies (undergraduate, master, doctoral), as well as within the specialist, applied and integrated studies, and they are almost equally represented at undergraduate and master studies.
- At undergraduate studies, courses dedicated to sustainable development are in most cases studied in the second or the fourth year of studies.
- Courses dedicated to sustainable development are in most cases elective (there are half as many compulsory courses as those that are elective).
- The largest number of courses on sustainable development belongs to the environmental and occupational safety engineering.

Despite greater recognition of the need and the importance to integrate SD into the engineering curricula, the number of technical faculties dedicated to the holistic development of engineering competencies for sustainable development is still limited. Most of the study programs are still focused on environmental engineering or energy, which indicates an implicit understanding of sustainability as environmental sustainability.

Certainly, the inclusion of courses focused on sustainable development issues can be seen as a starting point for institutions (such courses lead to the development of certain competencies), but it is unlikely that future engineers will be able to comprehensively integrate the sustainable development principles into their professional lives. The emphasis on adding new sustainability courses to the existing curriculum can be interpreted as a *separate sustainability* or as something subsequently added to the curriculum rather than as an integral part of sustainable engineering. Separately teaching students about sustainability and about key engineering concepts does not encourage them to include sustainability in their future professional practice. Wider intertwining of SD as a concept with the regular courses offers greater opportunities for students to incorporate SD and its principles into their professional lives, through raising their awareness and responsibility for the environment and their societies.

This paper points to the need to create the engineering curricula that will provide a complete contribution to sustainability (including economic, environmental, social and other topics). In addition, this paper indicates the directions for new research, that is, the future research should be focused on:

- the tools and indicators for assessing the quality of engineering education for sustainable development,
- determining the level of real competencies of future engineers in sustainable development, and
- determining the needs of specific industrial sectors in education for sustainable development, *i.e*. the creation of specialized programs, *etc*.

The results of the research can help the universities' leaders and the competent bodies of the Ministry of Education improve the planning of changes in the engineering education, that is to design the educational reforms in order to promote learning about sustainability and to encourage students to think about this topic to be actively involved in changes towards sustainable future. Also, the results can bridge the differences between the current activities at the university and the competencies the future engineers should have, *i.e*. what they should achieve as decision makers on the path to sustainable development.

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References

[1] Mulder, K. F., *et al.*, Educating Engineers for/in Sustainable Development? What We Knew, What We Learnd, and What We Should Learn, *Thermal Science, 14* (2010), 3, pp. 625-639
[2] Mulder, K. F., *et al.*, How to Educate Engineers for/in Sustainable Development: Ten Years of Discussion, Remaining challenges, *International Journal of Sustainability in Higher Education, 13* (2012), 3, pp. 211-218
[3] Taoussanidis, N., Antoniadou, M., Sustainable Engineering Education: Justified and Justifiable, Proceedings (P. Dondon, O. Martin), Latest Trends on Engineering Education, *Proceedings*, 7th WSEAS International Conference on Engineering Education (EDUCATION'10), Corfu Island, Greece, 2010, pp. 428-434
[4] Rosen, M. A., Engineering Sustainability: A Technical Approach to Sustainability. *Sustainability, 4* (2012), 9, pp. 2270-2292
[5] Mihelcic, J. R., *et al.*, Educating Engineers in the Sustainable Futures Model With a Global Perspective, *Civil Engineering and Environmental Systems, 24* (2008), 4, pp. 255-263
[6] Quist, J., *et al.*, Backcasting for Sustainability in Engineering Education: The Case of Delft University of Technology, *Journal of Cleaner Production, 14* (2006), 9-11, pp. 868-876
[7] Sanchez-Carracedo, F., *et al.*, A Methodology to Analyze the Presence of Sustainability in Engineering Curricula. Case of Study: Ten Spanish Engineering Degree Curricula, *Sustainability, 11* (2019), 17, pp. 1-2
[8] Mesa, J. A., *et al.*, Sustainability in Engineering Education: A Literature Review of Case Studies and Projects, 2017, https://www.researchgate.net/publication/320008725_Sustainability_in_Engineering_Education_A_Literature_Review_of_Case_Studies_and_Projects
[9] Lourdel, N., *et al.*, Introduction of Sustainable Development in Engineers' Curricula: Problematic and Evaluation Methods, *International Journal of Sustainability in Higher Education, 6* (2005), 3, pp. 254-264
[10] ***, The Royal Academy of Engineering, Engineering for Sustainable Development: Guiding Principles, The Royal Academy of Engineering, London, 2005
[11] Mulder, K., Engineering Education in Sustainable Development: Sustainability as a Tool to Open up the Windows of Engineering Institution, *Bussiness Strategy and the Environment, 13* (2004), 4, pp. 275-285
[12] Huntzinger, D., *et al.*, Enabling Sustainable Thinking in Undergraduate Engineering Education, *International Journal of Engineering Education, 23* (2007), 2, pp. 218-230

[13] de Vere, I., *et al.*, Educating the Responsible Engineer: Socially Responsible Design and Sustainability in the Curriculum, 2009, https://www.researchgate.net/publication/267545610_Educating_the_responsible_engineer_Socially_responsible_design_and_sustainability_in_the_curriculum
[14] ***, UNESCO, Engineering: Issues Challenges and Opportunities for Development, UNESCO, Paris, 2010
[15] Vehmaa, A., *et al.*, Building a More Sustainable Society? A Case Study on the Role of Sustainable Development in the Education and Early Career of Water and Environmental Engineers. *Sustainability, 10* (2008), 8, pp. 1-18
[16] Colombol, C., *et al.*, A Study on Impact of the UN Decade of Education for Sustainable Development on Industrial Engineering Education, *Dirección y Organización, 56* (2015), July, pp. 4-9
[17] Al-Rawahy, K. H., Engineering Education and Sustainable Development: the Missing Link, *Procedia – Social and Behavioral Sciences,102* (2013), Nov., pp. 392-401
[18] ***, UNESCO, Agenda 21. Chapter 35. Science for Sustainable Development, UNESCO, Paris, 1992
[19] ***, UNESCO, Agenda 21. Chapter 36. Promoting Education, Public Awareness and Training, UNESCO, Paris, 1992
[20] ***, UNESCO, UNESCO Engineering Initiative, UNESCO, Paris, 2012
[21] ***, UNESCO, UNESCO Sustainable Engineering, UNESCO, Paris, 2012
[22] Fenner, R. A., Embedding Sustainable Development at Cambridge University Engineering Department, *International Journal of Sustainability in Higher Education, 6* (2005), 3, pp. 229-241
[23] Glavic, P., *et al.*, Engineering Education: Environmental and Chemical Engineering or Technology Curricula - A European Perspective, *European Journal of Engineering Education, 34* (2009), 1, pp. 47-67
[24] Segalas, J., *et al.*, What Do EESD "Experts" Think Sustainability Is? Which Pedagogy Is Suitable to Learn It? Results From Interviews and Campus Analysis Gathered at EESD 2008, *International Journal of Sustainability in Higher Education, 13* (2012), 13, pp. 293-304
[25] Braun, D., Teaching Sustainability Analysis in Electrical Engineering Lab Courses, *IEEE Transactions on Education, 53* (2010), 2, pp. 243-247
[26] Segalas, J., What has to be Learnt for Sustainability? A Comparison of Bachelor Engineering Education Competenves at Three European Universities, *Sustainability Science, 4* (2009), 1, pp. 17-27
[27] Svanstrom, M., *et al.*, Embedding of ESD in Engineering Education - Experiences from Chalmers University of Technology. *International Journal of Sustainability in Higher Education, 13* (2012), 3, pp. 279-292
[28] Jahan, K., *et al.*, Environmental Education for All Engineers, *Water Science & Technology, 49* (2004), 8, pp. 19-25
[29] Paten, C. J. K., *et al.*, Engineering Sustainable Solutions Program: Critical Literacies for Engineers Portfolio, *International Journal of Sustainability in Higher Education, 6* (2005), 3, pp. 265-277
[30] Azapagic, A., *et al.*, How Much Do Engineering Students Know About Sustainable Development? The Findings of an International Survey and Possible Implications for the Engineering Curriculum, *International Journal of Engineering Education, 30* (2005), 1, pp. 1-19
[31] Nikolić, V., *et al.*, Students' Attitudes Towards Sustainable Development in Serbia, *International Journal of Sustainability in Higher Education, 21* (2020), 4, pp. 733-755
[32] Abdul-Wahab, S. A., *et al.*, The Need for Inclusion of Environmental Education in Undergraduate Engineering Curricula, *International Journal of Sustainability in Higher Education, 4* (2003), 2, pp. 126-137
[33] Petković, A., Who are Engineers - Professions that Carry the Title Engineer (in Serbian), 2019, https://beleske.com/ko-su-inzenjeri-struke-koje-nose-zvanje-inzenjera/

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