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STEM on Demand – Can Current State of Higher Education Infrastructure Meet Expectations?

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Abstract

One of the biggest challenges facing the education system in Bosnia and Herzegovina is bridging the gap between the current state of higher education and the demand for research, innovation and a robust STEM (Science, Technology, Engineering, Mathematics) curriculum. Higher education instiutions (HEIs) face poor R&D infrastructure while companies struggle with limited resources and the lack of internal researchers, all of which affect their capabilities to utilize university knowledge and research that will lead to further collaborations and innovations in STEM. Universities are primarily seen as a source of future employees as well as as a source of knowledge and innovation. This study aims to provide an overview and systematic analysis of the current state of scientific and research infrastructure and human resources in public and private universities located in the Sarajevo Canton region. This is done by using primary data collected through semi-structured interviews and a self-reporting comprehensive questionnaire in order to identify areas where further reforms and investments are needed. An analysis of the secondary data sources, such as current strategic documents and the existing assessments of education, was conducted. Consequently, this study offers several practical implications, including policy recommendations in areas such as higher education, research infrastructure and academic excellence, cooperation with the private sector, and IT infrastructure improvements.

Keywords: STEM, education, infrastructure, development

Introduction

Higher education development and modernization are ranked high on the list of priorities at both national and regional levels in countries across Europe. The decision-making processs in education is almost always tied to economic strategies and planning. The Europe2020 Strategy is a 10-year European Union (EU) road map for growth and jobs that promote smart, sustainable, and inclusive growth, emphasizing in particular the importance of education in the overall process. This stategic document identified several significant initiatives, including: Education and training – ET2020 (Council, 2009); Rethinking education: investing in skills for better socio-economic outcomes (European Commission, 2012); Modernising universities (European Commission, 2006); Internationalisation in European

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higher education (EUA, 2013), among others. When it comes to education system reforms, a majority of those focus on

- Increasing the number of university graduates;
- Improving the quality and relevance of teaching and learning;
- Promoting student and teaching staff mobility and cross-border cooperation;
- Strengthening the „knowledge triangle" that links education, research and innovation;
- Creating effective governance and funding mechanisms for higher education (European Union, 2011; EUA, 2013; European Commission, 2013):

In the overall process, it is universities that provide new, contemporary knowledge that is keenly sought after and applicable in national economies, with the ultimate goal of improving national competitiveness, exporting growth, employment and general economic and social progress. However, countries today face challenges such as a lack of collaboration between higher education institutions (HEIs) and industry, university collaboration (especially in terms of new curriculum development), infrastructure investments and improvements, educated academic staff, adequate management, among others. Thus, the question that arises is: is the current education model, with its respective capital (human and other forms), fit for modern STEM (Science, Technology, Engineering and Math) education and demands? Given Bosnia and Herzegovina's (B&H) strategic commitment to European integrations, work needs to be done to create a „knowledge-based economy", i.e. an economy that will be competitive in both regional and global contexts. Continuous modernization of higher education system is becoming an imperative, subject to long and demanding reforms. Recognizing the complexity of higher education systems and the fact that HEIs are often the driving force behind all major social changes, this study aims to answer the following research questions (RQ) in the context of Bosnia and Herzegovina:

RQ1. What is the current state of human resources in Sarajevo HEIs?

RQ2. What are HEIs member's assessments of the quality of available research and scientific infrastructure?

RQ3. What are the main limitations in STEM research and scientific activities identified by the HEIs members?

The research focus in this study is on higher education in the Sarajevo Canton[1], its existing human, financial and infrastructural resources in the context of wider development goals and creation of knowledge-based economy. A comprehensive analysis was conducted to assess the existing state of education system and its research infrastructure in Sarajevo. This analysis included an evaluation of key resources and processes based on both primary and secondary data sources, followed by interpretation and discussion with the final goal of defining policy recommendations and promoting evidence-based decision making in education. Primary data sources include semi-structured interviews and a self-reporting comprehensive questionnaire in order to identify areas where further reforms and investments are needed, while secondary data sources include strategic documents and the existing assessments of education system.

In the Section 2 of this paper, we discuss a conceptual background of the study by presenting a literature review on the importance of building and modernizing capacities and infrastructure in education. We also discuss the contemporary views on STEM and fully utilizing its potential. In Section 3, we provide a brief overview of higher education system in Bosnia and Herzegovina with its legislative and institutional framework and strategic goals. The methodological framework of this study is presented in Section 4. Results and discussion are provided in Section 5, with specific references to human resources, financial, technical and administrative conditions, and research infrastucture. Concluding remarks, research limitations and indications for future research are in Section 6. Practical implications and recommendations are presented in the final section.

Conceptual Background

Literature review on the importance and challenges of STEM education

STEM education has become a very important topic in contemporary discussions and education initiatives and are dominating the global landscape of educational reform (Yanez et al., 2019). It is considered an essential preconditon to a country's innovative capacity-building and competitiveness. Development strategies of countries around the world are focused on building knowledge-based economies; however, most of the countries are most concerned about the possible shortages of STEM knowledge, both on the students' and educators' sides. The demands for STEM are changing and STEM is becoming more globalised (Seymour & Hewitt, 1997; Prados, 1998; Butz et al., 2006). STEM courses have become very prestigious, attracting the best students with the promise of prestigious careers and high salaries. Public returns on investment into STEM education are focused around the significant contribution of STEM education to

[1] Sarajevo Canton is one of 10 cantons of the Federation of Bosnia and Herzegovina in Bosnia and Herzegovina.

different health research aspects, smart energy solutions etc., that eventually contribute to both an individual's and society's welfare. However, there is a concern that even though access to STEM has increased, the success and retention of these students has not signficantly increased (Sithole et al., 2017). Carlisle & Weaver (2018) address the need for more STEM graduates and for changing the nature of STEM education, focusing on the changes in teaching, promotion, scholarships, etc. Even though STEM is dominating in the global education reform debates, it is implemented into traditional pedagogies, systems and practices (Yanez et al., 2019) and fails to translate innovations in policy into innovations in pedagogy and thus neglecting the impact of science and technology in physical and social worlds of today (Murphy et al., 2017; Zeidler, 2016).

Literature review on HEIs- industry collaboration and its constraints

STEM education today is a vehicle for innovation and technical solutions to global problems (Weinstein et al., 2016). During their higher education, students from STEM fields are exposed to the scientific and technical knowledge generated by academic research (Colombo & Piva, 2020) and STEM graduates become entreprenuers themselves, sometimes immediately after graduation (Colombo et al., 2010). Findings on the population of graduates (2005-2009) from Milan (Italy) reveal that graduates are more likely to become entrepreneurs immediately after graduation if their university curricula are more specialized in a limited number of scientific and technical fields (Colombo & Piva, 2020). Collaboration between universities, research institutions, and businesses will increase innovativness in the business sector and thus improve the competitiveness of national economies (Lööf & Broström, 2008; Belderbos et al., 2004; Lööf & Heshmati, 2002; Buganza & Verganti, 2009). However, knowledge transfer can only be improved if an adequate infrastructure, in forms of networks and connections, is established. In order to fully utilize the possibilites and multiple benefits of STEM education, it is necessary to understand the nature of relationships among key stakeholders and to build STEM networks (Carlisle & Weaver, 2018). STEM networks of different institutions and centers are one of the ways of improving knowledge transfers, which is a precondition for radical innovation (Mohnen & Hoareau, 2003). These networks can take different forms, such as R&D alliances (Hagedoorn et al., 2000); innovation-centred collaboration along the supply chain (Harabi, 1998); or informal social relationships among members of different organizations (Gulati, 1998; Oliver & Liebeskind, 1998). Innovation can only happen at high levels of collaboration and networks, thus leading to open innovations. In this environment, higher education is an important partner to businesses and other stakeholders (Laine et al., 2015). Higher education institutions are an important source of innovation since these institutions educate future generations of workers, create new and improve existing knowledge, and in the end have significant economic and social benefits for societies in general (Cohen et al., 2002; Mansfield, 1991; Pavitt 1991; Salter & Martin, 2001). The main constraints to digital innovation at HEIs are limited infrastructure and resources, a lack of funding opportunities, insufficient technological resources, a conservative academic culture, and a lack of technical support (Vicente el al., 2020). Thus, it is of imense importance to minimize the contraints and allow STEM to reach its full potential by contributing to the overall economic goals.

Higher Education in Bosnia and Herzegovina

Higher education in B&H is regulated by the Framework Law on Higher Education in Bosnia and Herzegovina (Official Gazette of B&H, 59/07, 59/09), while the Law on Higher Education of the Sarajevo Canton (Official Gazette of the Sarajevo Canton, 33/17) is coordinated with the Framework Law. On the basis of the Framework Law on Higher Education, the Law on Higher Education in the Republika Srpska, ten cantons in the Federation of B&H (FB&H) and the Brcko District of B&H are also coordinated, and have completely transferred B&H education to the Bologna process. In addition to the Bologna reforms, the education system in B&H is in the process of transition, undergoing a demanding process of adapting education to market trends. Although B&H signed the Bologna Declaration in 2003, progress in this area was only visible after the adoption of the Framework Law on Higher Education in 2007. This law established two new state institutions, the Agency for the Development of Higher Education and Quality Assurance and the Center for Information and Recognition of Documents in the Field of Higher Education. Accreditation of higher education institutions is performed by the Agency for the Development of Higher Education and Quality Assurance, which has so far accredited 30 public and private institutions in B&H (HEA)[2]. In order to further integrate into the European Higher Education Area to ensure the quality of higher education and to internationally recognize diplomas of foreign higher education institutions, further capacity building of existing institutions is needed. This would ultimately accelerate the transition between education and the labor market. With regard to B&H strategic commitment to European integrations, it is necessary to keep in mind the current trends in the development of education in EU countries. The higher ed-

[2] Agency for Development of Higher Education and Quality Assurance of Bosnia and Herzegovina

ucation system of B&H needs to be in line with European trends because, given the importance of higher education, only cooperation and coordination of higher education, technology, innovation and the private sector can improve national competitiveness in the regional and European context. The field of education is significant for B&H from the perspective of the negotiation process for a full EU membership. Namely, from the experience of the Republic of Croatia, we can see that the negotiations within the chapter of Education and Culture are a framework for the internationalization of education of the candidate country.

Higher education in B&H, as in most countries in the region, has been the subject of long and demanding reforms. In a significant number of cases, reform processes in the last two decades were supported by a large number of international organizations and institutions. Current priorities of higher education in B&H are: good governance and management; resources; the relationship between the labor market and higher education; qualification standards; student experience; internationalization and statistics (EU/CoE, 2015). In terms of entity level, the Federal Ministry of Education and Science defined its goals for the period 2012-2022 in FMON (2012), while government of Republika Srpska also defined its strategic goals for higher education for the period 2016-2021 (Vlada RS, 2016). Highly decentralized education decision-making in B&H should enable institutions to be more flexible and specific in defining policies and instruments. However this is not the case.

Methodological Framework

Higher education institutions are key actors in the education process in the Sarajevo Canton, where one public (University of Sarajevo) and three private universities (University of Sarajevo, School of Science and Technology; International University of Sarajevo; and International Burch University) are located. All of these institutions are accredited by the Agency for Development of Higher Education and Quality Assurance. Taking into account that almost half of the graduates (46.5%) in B&H graduated from the universities in the Sarajevo Canton and that the oldest and largest university in B&H (University of Sarajevo)[3] is located in the Sarajevo Canton, the role of this region in the overall education is highly significant for the entire country.

This study employs both primary and secondary data sources in the process of answering the main research question. Primary data sources include the conducted semi-structured expert interviews and self-reporting comprehensive questionnaire. Interviews were held with representatives of key higher education institutions in Sarajevo Canton between September and December of 2019. A self-reporting comprehensive questionnaire was distributed during the intervews with the main aim of assessing the current state of research infrastructure including research centers and laboratories. The following universities participated in the study: University of Sarajevo (UNSA); International University of Sarajevo (IUS) and Burch International University (Burch). A descriptive study approach has been implemented. The secondary data sources include publicly available data from the universities‘ websites, scientific research institutions and other data sources such as offical statistics from different administrative levels and education institutions. This analysis includes an overview of the existing infrastructure, adequate administrative support, financial and technical conditions, and an analysis of academic and research staff at higher education institutions in the Sarajevo Canton.

[3] Around 91.6% of the total students in the Sarajevo Canton are enrolled at the University of Sarajevo (BHAS).

Results and Discussion

The results are presented in two different areas, i.e., human resources and infrastructure according to research questions.

Human resources – current state and future development

The data collected show that the total number of academic staff participating in the teaching and research processes at higher education institutions in the Sarajevo Canton is 2690. Academic staff (those directly involved in the teaching and research process) total 1476 and are employed full-time. Around 88.5% of them are employed by UNSA, and the other 11.5% by other private universities (Table 1).

Table 1. Structure of academic staff by title and type of employment at higher education institutions in Sarajevo Canton

Academic title	Full time employed	Shared employment	Visiting academic staff
Professors	232	162	124
Associate professors	324	141	148
Assistant professor	434	152	174
Senior teaching assistants	304	99	87
Assistants	158	84	41
Lectors	24	2	0

Source: author's calculations (questionnaire and IBU;IUS; SSST).

In percentages, this means that 55% of academic staff are employed full-time, 24% are academic staff with shared employment (usually 20% or maximum 50%), while visiting academic staff from other universities in B&H or abroad make 21% of the total academic staff. An analysis of the progression of academic staff was conducted, in the context of the advancement of the existing academic staff and the average number of new employees at universities, and it is presented in Table 2.

As can be seen from Table 2, there is a noticeable imbalance between full professors, associate professors, and assistant professors on the one hand and senior teaching assistants and assistants on the other hand. Therefore, one of the strategic planning measures should be aimed at improving this relationship and preventing academic aging at the higher education institutions in Sarajevo Canton. Regarding the quality of teaching and research activities of academic staff, the majority of interviewees pointed out the need to improve the following areas: (1) financial conditions, (2) technical conditions and (3) administrative support. It is necessary to establish transparent and publicly available funding principles for universities in the Sarajevo Canton area, including public and private universities; that is, to ensure uniform criteria for allocation of funds from the Sarajevo Canton budget, as well as the criteria and procedures for determining the amount of tuition and/or the cost of studies at both public and private universities. In order to improve the quality of teaching, as well as scientific and research activities, it is necessary to provide adequate funds in the form of a fund to support these activities, and to establish an adequate system of rewarding academic excellence. The implementation of a high-level teaching process and high-quality scientific and research projects (scientific and commercial research) requires technical conditions, which include, among other things, proper equipment such as classrooms, laboratories and research centers. Therefore, it is necessary to provide adequate material, and technical and infrastructural prerequisites for a high-standard performance.

Higher education infrastructure

The state of higher education infrastructure in the Sarajevo Canton is analyzed based on both primary and secondary data sources. The research shows that all universities in the Sarajevo Canton have their own library holdings; however, there is a trend of decreasing investment in enriching them. One of the measures that would significantly improve the scientific and research work in higher education institutions would be the provision of relevant literature at the universities and university libraries, as well as electronic access to databases of scientific and professional publications. A classification of laboratories and research centers by purpose in higher education institutions in the Sarajevo Canton has been carried out. The classification of laboratories and their numbers is shown in Table 3 below.

Table 2. Number of newly employed and promoted academic staff at higher education institutions in Sarajevo Canton

	Promotion at home university		Newly employed at University	
	UNSA*	Private universities in Sarajevo Canton**	UNSA*	Private universities in Sarajevo Canton**
Professors	33.7	6.3	0.0	1.8
Associate professors	71.0	9.3	0.0	2.7
Assistant professor	100.0	26.8	0.0	10.5
Senior teaching assistants	46.3	33.5	0.0	7.7
Assistants	35.0	10.0	0.0	1.2

* Analysis conducted on the sample from the previous three academic years and the number of employees at the expense of Canton Sarajevo.

** Analysis conducted on a sample of the previous six academic years and the number of employees at the private university.

Table 3. Classification of laboratories by purpose

Purpose	Total number at UNSA	Total number at private universities in Sarajevo Canton
Laboratories for teaching	170	5
Laboratories for scientific and research activities	70	8
Laboratories for commercial research	19	0
Research centers (institutes) within universities	6	1
Research centers (institutes) within faculties	35	0

Source: authors‘ calculations (questionnaire and IBU;IUS; SSST)

A majority of the existing teaching and research laboratories are available at the University of Sarajevo. UNSA has over 95.5% of the total available laboratory resources and research centers (institutes) in the Sarajevo Canton. The analysis found that in addition to the existing capacities, there is a need to establish new laboratories that would be used in teaching and research. Over 10% of teaching and research laboratories are no longer usable for their primary purpose. It is encouraging to see that there more than 21% of teaching laboratories meet all the prerequisites. This percentage is slightly higher for laboratories exclusively dedicated to scientific research (34%). However, more than 50% of the existing laboratory resources at UNSA need to be modernized. Also, a number of laboratories primarily intended for scientific research do not have adequate human resources. There are 19 commercial research laboratories operating or under development at UNSA, two of which are in the process of being established and another two in the process of being closed. Taking into account the existing human resources, it is evident that there are preconditions for better functioning of the existing ones, as well as the establishment of new commercial laboratories, which would contribute to the achievement of one of the strategic goals of higher education development, which is cooperation with the real sector.

Concluding Remarks

Globalization, and especially the Europeanisation of higher education, is a key trend in European countries, but at the same time presents a challenge for higher education in Bosnia and Herzegovina. Globalization of higher education implies observation of universities outside the national context, while Europeanization of higher education refers primarily to the case of internationalization of higher education, but inside a European context (limited internationalization to European countries). The importance of education, especially higher education, for the long-term economic and social development of Bosnia and Herzegovina is immeasurable.

Education reform in Bosnia and Herzegovina has been on the agenda for a considerable length of time, but constraints still persist. A highly decentralized legislative framework and decision-making system as well as a lack of collaboration in planning and implementation processes are limiting progres in this area. This research conducted in the Sarajevo Canton among one public and three private universities has shown an imbalance among academic staff in terms of academic aging at HEIs in the Sarajevo Canton. In terms of available infrastructure for STEM research activities, the interviewees have reported that more than 50% of the existing laboratories at UNSA needs modernization. Qualitative methods, in terms of semi-structured interviews and limiting the scope of the research to one region, are the main limitations of this study. Future research in STEM higher education in Bosnia and Herzegovina should be focus on issues such as: the quality of STEM education, differences between STEM education provided by public and private universities, and the gender gap in STEM, among others.

Recommendations

In order to improve scientific production in the Sarajevo Canton, it is necessary to:

- Increase investments through the Fund for Support of Scientific Research and Innovation and stimulate further investments;
- Enrich access to databases of scientific journals and publications and expand the library stock of higher education institutions, which will lead to increased academic and scientific excellence;
- Increase financial and other forms of support for the professional development of teaching and research staff;
- Establish mechanisms that would further regulate the maximum workload of teachers and associates in higher education in the Sarajevo Canton, with the aim of reducing the teaching load and increasing participation in scientific and research projects.

The analysis also identified that there is a need for renovation of the existing and the establishment of new laboratories for use in the teaching process, as well as for scientific and research work. It is necessary to provide adequate investment in the modernization of equipment, laboratories, and other infrastructural capacities of higher education institutions in the Sarajevo Canton (libraries, adequately equipped classrooms, student accommodation facilities, campus, etc.). The following is necessary:

Upgrade and expand the existing higher education information and communication structure in the Sarajevo Canton;

Upgrade and integrate the existing higher education information systems and link them to systems in the field of science and lifelong learning (registry of researchers) in such a way that they provide access to comprehensive and high quality information for higher education decision-making, research, and evidence-based policy).

Stimulate cooperation and networking of higher education institutions and their organizational units in the Sarajevo Canton in order to use the existing human and other resources more efficiently.

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NA-MA na zahtevo – je trenutna visokošolska infrastruktura zmožna izpolniti pričakovanja?

Izvleček

Eden največjih izzivov, s katerimi se sooča izobraževalni sistem v Bosni in Hercegovini, je premostitev vrzeli med trenutnim stanjem visokega šolstva in povpraševanjem po raziskavah, inovacijah in učnem načrtu za NA-MA (naravoslovje, tehnika, inženiring, matematika). Visokošolske ustanove se soočajo s slabo infrastrukturo raziskav in razvoja, medtem ko se podjetja spopadajo z omejenimi sredstvi in pomanjkanjem internih raziskovalcev, kar vpliva na njihove zmožnosti izkoriščanja univerzitetnega znanja in raziskav, ki bi lahko privedlo do nadaljnjega sodelovanja in inovacij znotraj NA-MA. Univerze veljajo predvsem za vire bodočih zaposlenih in tudi za vire znanja in inovacij. Cilj študije je podati pregled in sistematično analizo trenutnega stanja znanstvene in raziskovalne infrastrukture ter kadrov v javnih in zasebnih univerzah na območju kantona Sarajevo. To je bilo izvedeno z uporabo primarnih podatkov, zbranih s pomočjo polstrukturiranih intervjujev in obsežnega samoocenjevalnega vprašalnika, s katerimi smo identificirali področja, kjer so potrebne nadaljnje reforme in investicije. Izvedena je bila tudi analiza sekundarnih virov podatkov, kot so veljavni strateški dokumenti in obstoječa vrednotenja izobraževanja. Posledično ima ta študija številne praktične vidike, vključno s priporočili glede politike na področjih, kot so visoko šolstvo, raziskovalna infrastruktura in akademska odličnost, sodelovanje z zasebnim sektorjem in izboljšave informacijske infrastrukture.

Ključne besede: NA-MA, izobraževanje, infrastruktura, razvoj