STRENGTHENING THE RESEARCH OF KEY ENABLING TECHNOLOGIES FOR NEW INNOVATIONS*

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ABSTRACT

The development of science and technology in recent times is hosting major changes with the emergence of new key concepts, e.g. nanotechnology, micro nanoelectronic, etc. Technologies are changing the way in which society operates and there is a need to ensure that they are used in a best possible way. The way to address these new concepts is crucial for achieving economic and social prosperity and an obvious indicator of a country's ability to maintain a sustained growth in accordance with the latest advances. In Croatia, key enabling technologies (KETs) are recognized as one of the two cross-cutting topics able to create the biggest addedvalue and foster the emergence of new economic activities, the rising of the productivity of the Croatian economy and the creation of new and sustainable job opportunities in the Croatian Smart Specialization Strategy. In addition, Croatian scientific and research institutions have a lot of experience in KET-related projects funded by the European Union, either as a partner in international projects or having their own project. The biggest Croatian stren-gth in KET are open economy and relatively high-level of internationalisation of national companies, as well as the access to a pool of high-skilled workers and good quality infra-structures with substantial investments in the fields of transportation, telecommunications and energy. However, there is limited colla-boration between industry and academia in R&D and there is a need to further support and train SMEs.

Keywords: innovation, research and development, KETs, international cooperation, economic development.

JEL: O31, O32, O33, O19

1. INTRODUCTION

Key Enabling Technologies (KETs) provide the basis for innovation in a wide range of industries and due to their potential to help industry grow, KETs are a priority for European industrial policy. Their impact on the EU economy is already considerable: in 2013, products enabled by KETs amounted to 953.5 billion euro, 19.2% of the total EU-29 manufacturing. Research activity and higher education in Croatia did not stress topics related to KETs so far in their national strategic documents, plans and programmes. Unlike national acts, some sectorial strategic documents have policy measures dedicated to KETs, such as the Strategy of Education, the Science and Technology Strategy (2014), the Croatian Smart Specialization Strategy (2016-2020), the Strategy for Lifelong Career Guidance in the Republic of Croatia 2016-2020 and the Vocational Education and Training Development Programme (2016-2020). This paper gives the overview of Croatian regulatory

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framework and strategic plans related to KETs and the results of the research conducted to collect feedback on the general needs by Vocational Education and Training towards KETs. The aim of this paper is to analyse the current situation related to importance of KETs in Croatia, with special emphasis on nanotechnology, biotechnology, and advanced materials.

2. PREVIOUS RESEARCH

KETs are recently recognised as an important field of scientific research through the Industry 4.0 concept. Fourth industrial revolution is characterised by the emergence of smart factories in which cyber-physical systems monitor physical processes and communicate with each other and human beings in real time. According to the Ciffolilli and Muscio (2018), KETs becomes increasingly important as a policy choices for future development.

Industry 4.0 was also a subject of the research made by Muscio and Ciffolilli (2019), who investigated the factors underlying the capacity to compete by integrating Industry 4.0 enabling technologies. According to them, regions that are more able to obtain EU funds by submitting competitive projects and becoming more central in research networks are also more likely to be characterised by a greater capacity to integrate Industry 4.0 technologies rather than focusing on one or few key research areas. Conversely, more peripheral regions are less capable of obtaining EU funds and are likely to have a more limited capacity to integrate Industry 4.0 technologies. However, national and regional governments may have an important role in facilitating catching up of their territories not only by reinforcing the local capacity to develop Industry 4.0 technologies but also by encouraging knowledge transfer via interregional and transnational cooperation.

The study prepared by Policy Department Economic and Scientific Policy, European Parliament (2014) examines the nature of KETs, and the drivers and barriers to their deployment. According to the Study, the development of KETs is strongly based on technology push and the development of advanced processes and products. Although some attention has been paid to the role and potential contribution of KETs to solving the grand challenges, there is both a need and an opportunity to link KETs and the grand challenges in a more direct manner. The KET concept is not yet widely applied beyond the level of the European Union (EU), even though many Member States address some or all of the six technologies and some countries (*e.g.* Austria and Belgium) align their own agenda to EU priorities. There is a considerable scope for countries to align their priorities and their policy timing more closely to the European KET agenda in order to benefit from potential synergies and policy complementarities and to develop combined funding strategies.

Montresor and Quatraro (2017) investigated the role of KETs in regional branching and analysed whether KETs knowledge could attenuate the effect that regional branching ascribes to technological relatedness, giving regions more scope for their technological diversification strategies. They found out that KETs have both, positive and negative effects – KETs negatively moderate the role of technological relatedness for regional specialization in new technological fields, but also KET knowledge increases the number of new technological specializations. Their overall conclusion is that the research results provide scientific support for the recent European Commission recommendation to plug KETs into the policy toolbox for smart specialization strategies inspired by regional branching.

According to Evangelista, Meliciani and Vezzani (2018), who also explored the specialisation of) EU regions in KETs, KETs could both enhance and hamper regional convergence.

On the one hand, the high knowledge and R&D intensity of these technologies may suggest that they can better be exploited by technologically leading regions. On the other hand, their pervasiveness and high range of applications also in traditional industries, can make them a potential source of growth and competitiveness for technologically laggard regions that are able to accumulate competencies in these technologies.

Paci, Lalle and Chiacchio (2013) analysed the intensity of initiatives in the area of higher education and training that are important enablers for a new trend for innovation. In the paper, they analysed trends for innovation highlighting higher education and training as an important pillar for change; academia-industry collaborations presenting determinants and five initiatives for high skilled jobs; and European stakeholders' views regarding the manufacturing sector focusing the priority themes in the process of change. The main conclusion of their paper is that for the development of process for change, universities and research institutions of the European countries hold a prominent role and are main stakeholders for a responsible future.

Słowikowski *et al*. (2018) analysed the impact of the digital revolution in vocational education and training (VET), with the aim to develop an ICT based collaborative training incorporating online collaborative learning solutions to be used in the field connected with VET education. They recognized KETs related skills and competences as needed in the current labour market, since they represent a 19% of all EU 28 production (about 3.3 million jobs in 2013) and are connected with a wide range of product applications such as developing low carbon energy technologies, improving energy and resource efficiency, and creating new medical products. They also have a huge potential to fuel economic growth and provide jobs (Słowikowski *et al*., 2018, pp. 020070-2 - 020070-3). The conclusion of their analysis is that further development of IT solutions, especially towards the use of artificial intelligence, Internet of things, human-machine communication, and Industry 4.0 will force a new approach to the teaching process and cooperation, because the opportunities to acquire and use knowledge will be greater.

In Croatia, KETs related research was conducted by Prester *et al*. (2016), who investigated barriers to the implementation of KETs in Croatian companies. The research showed that in Croatia, 28% of the surveyed companies do use some of the KETs.

3. RESEARCH METHODOLOGY

The results of the research presented in this article are based on the desk analysis and data analysis further backed up with qualitative methods. Desk analysis included an in-depth review of the relevant scientific literature (books, articles) and available Internet sources. For the purpose of gathering the results of the relevant scientific research, scientific research platforms were extensively searched (*e.g*. Google Scholar, the Web of Science, Scopus, *etc*.) by key words such as "innovation, research and development, KETs, international cooperation, economic development, education."

The results of desk analysis were enriched with the qualitative research methods out of which semi-structured questionnaires, in-depth interviews and structured workshops were conducted. The qualitative part of the research was conducted by gathering 27 answered surveys. Different stakeholders participated and provided an insight to the current situation: VET providers, students, enterprises and workers, local/regional authorities, *etc*. Out of 27 respondents who filled out the questionnaire, ten completed the entire questionnaire, eight completed part related to nanotechnology, three completed part related to biotechnology, and two of them focussed on advanced materials. Four respo-

ndents met the content of the questionnaire related to both, nanotechnology and advanced materials.

4. RESULTS AND DISCUSSION

Although strategic framework for the development of KETs in Croatia is relatively scarce and fragmented, Croatian scientists gained a lot of of experience related to KETs through KET- related projects. However, the transfer of this knowledge to the Croatian economy is not at a satisfactory level and key obstacles are the lack of managerial and entrepreneurial knowledge and skills that would bring the achievements of nanotechnology, biotechnology and advanced materials into everyday practice in the industry and business sector.

Most of the respondents are university graduates (42.31%) and have postgraduate level of education (42.31%), followed by upper secondary education/training (11.54%) and secondary school (3.85%). None of the respondents selected primary school as their level of education. Of the respondents who listed "University graduate" as the level of education, five pointed out the Faculty of Electrical Engineering, two the Faculty of Chemical Engineering and Technology, and one each the Faculty of Graphic Arts and the Faculty of Forestry. Others did not specify the name/level of degree.

Regarding the number of employees in the company or institution, 44.44% of the respondents said that they work/research in a company or institution with more than 250 employees, 40.74% in a company or institution with 51-250 employees and 14.81% in a company or institution with 11-50 employees. None of the respondents work or research in the company or institution with 10 or less employees.

Most of the respondents, 18 of them (66.67%) are located in Zagreb, three (11.11%) in Varaždin, two (7.41%) in Slavonski Brod and Dubrovnik and one (3.70%) in Sveta Nedelja and Pula.

Answering the question if they are familiar with KETs or work with them, 85.19% respondents stated that they are familiar with nanotechnology, 55.56% are familiar with biotechnology and the same number of respondents are familiar with advanced materials.

Half of the respondents have less than a year of prior experience in KETs, and one third has more than five years of experience in KETs. Three out of twenty-four respondents who answered this question have 3-5 years of

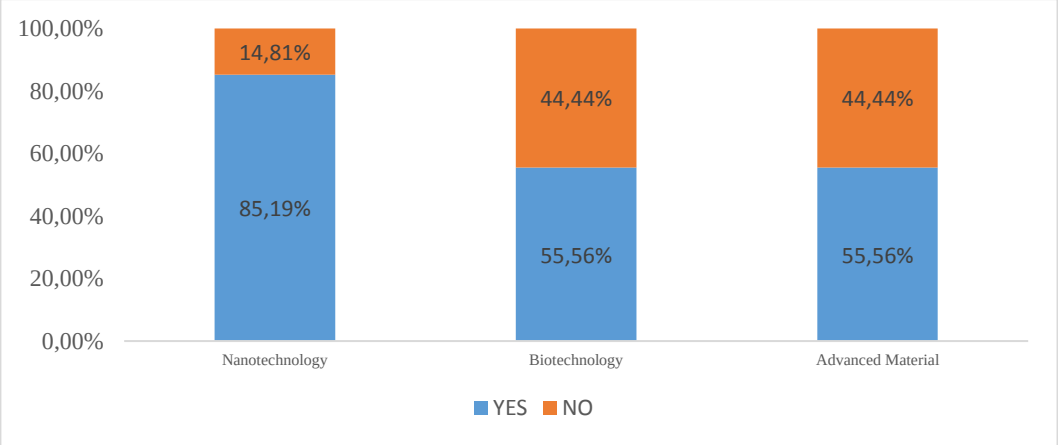

Figure 1. *Recognition of KETs*

Source: Authors' own work

experience in KETs and only one person (4.17%) has 1-3 years of experience in KETs. The research findings have shown that general skills and knowledge are of little relevance in present, especially financing KETs projects, innovation marketing and technologies commercialization, patents, and other intellectual property rights. These skills, now designated as deficient, are also designated as necessary in the following 10-20 years.

The respondents were asked the same questions, which now focused on those skills related to nanotechnology. Regarding the relevance of those skills and according to the respondents' answers, currently all skills are of average importance in the long term (10-20 years), knowing the skills related to nano-technology will be the key. According to the respondents, most relevant skills related to nanotechnology in the next 10-20 years will be energy at nanoscale, integration of nano-technology to food, medicine and materials, and renewable nanomaterials and potential uses.

A separate section of this survey dealt with the knowledge on biotechnology. The results showed specifically that at this moment the respondents consider that almost every biotechnology skill is of average relevance for a business or work. In the long term they consider that these concepts will bear a higher relevance or even be essential, especially in the case of industrial technologies for the

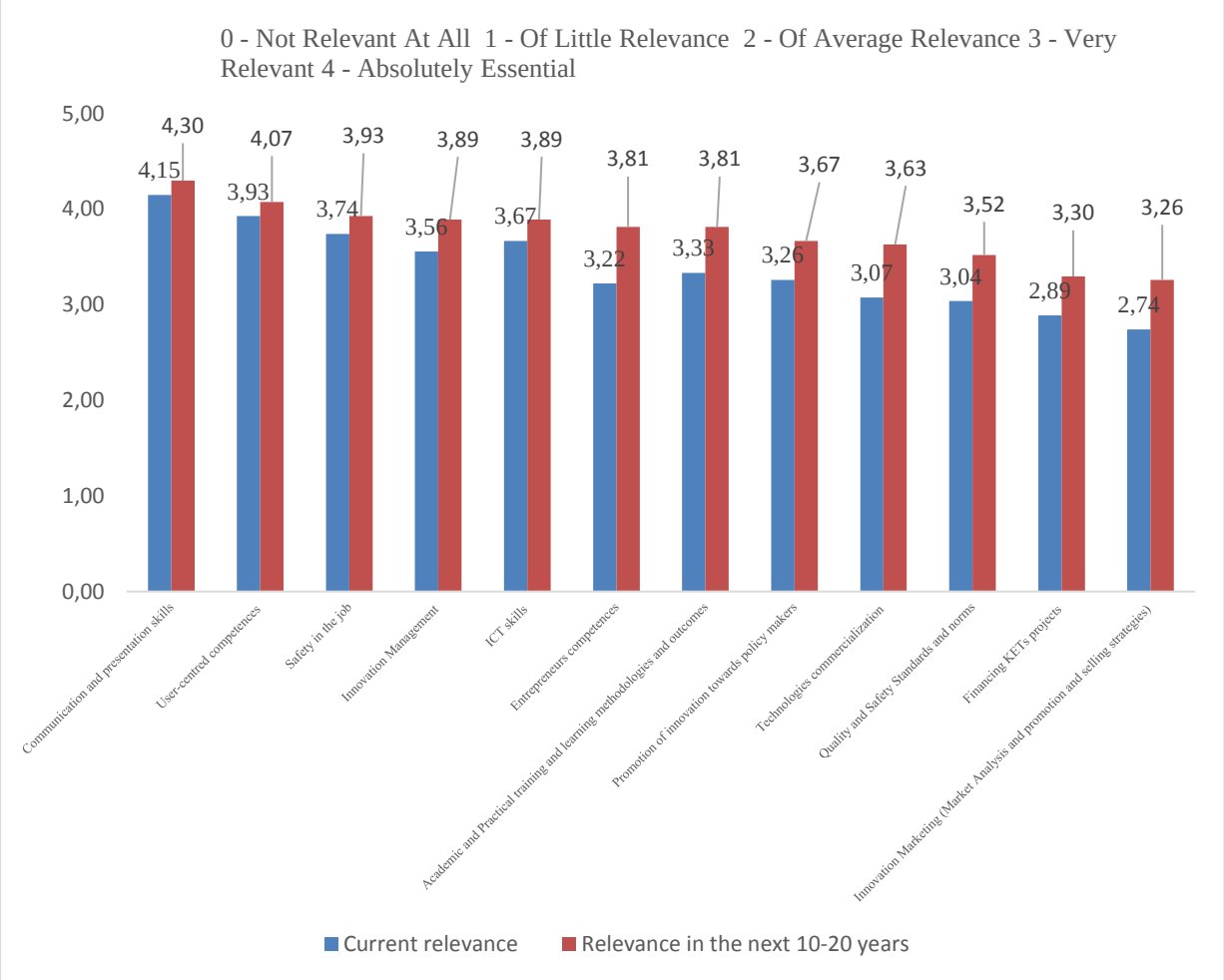

Figure 2. *Importance and relevance of general skills to the business/work*

Source: Authors' own work

production of biotechnological products, waste treatment and bioremediation and decontamination, and energy production from biological sources (bioethanol, methane, biogas).

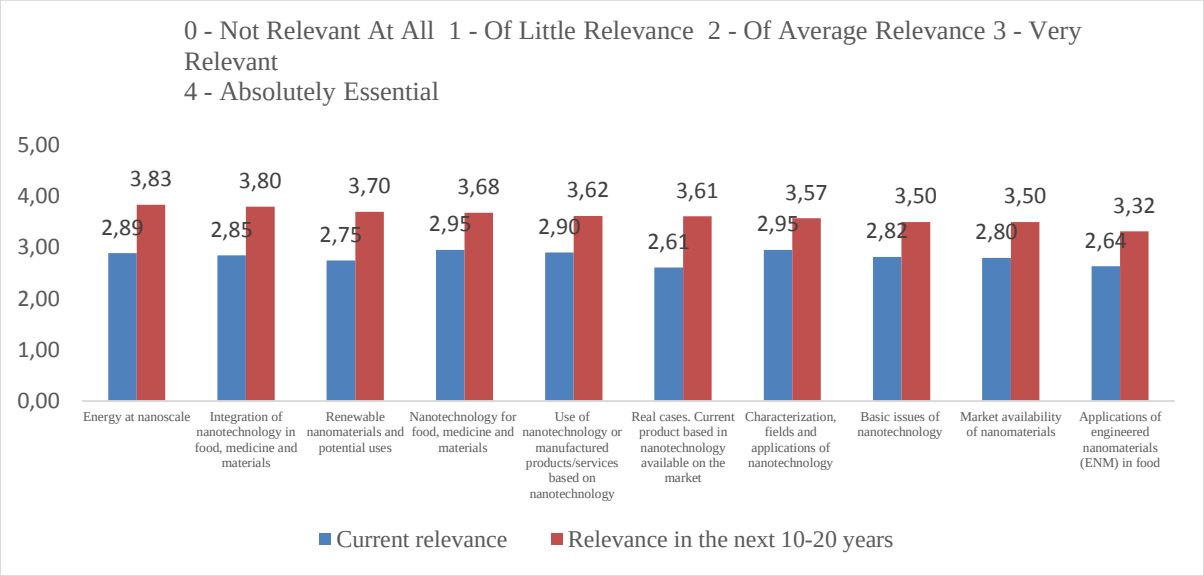

Figure 3. *Importance and relevance of skills to the business/work related to the nanotechnology*

Source: Authors' own work

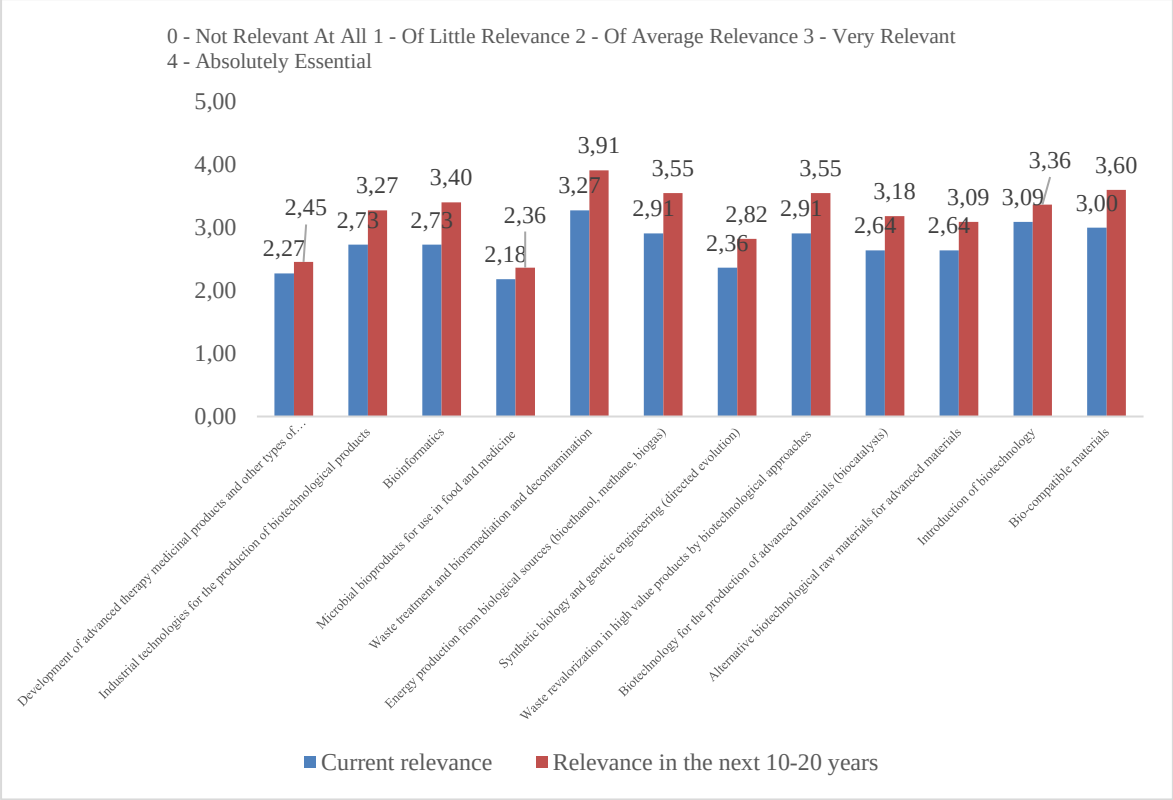

Figure 4. *Importance and relevance of skills to the business/work related to the biotechnology*

Source: Authors' own work

Additionally, the survey focused on the data related to the last KET researched in the scope of the BRACKET project, advanced materials. The respondents were asked about the importance of several skills related to advanced materials at present and in the long term.

Regarding the current relevance of skills related to advanced materials, those skills are rated as more relevant than two KETs previously analysed. All the skills were classified as of average relevance with the exception of the manufacturing of materials with advanced properties, wood composites, the use of zeolite, fabric materials and natural minerals (in food, waste treatment, environmental protection, air pollution, *etc*.) and graphene and carbon-based materials. Most of the skills were pointed out as very relevant in the medium and long term.

Finally, the respondents were asked to write down the three most relevant skills regarding KETs for the near future. Despite awide range of opinions, the greatest number of votes was given to Financing KETs projects, Innovation management and Academic and practical training and learning methodologies and outcomes (*e.g.* the use of VET programs to improve knowledge of KETs). Technologies commercialization (Patents and IPR) and entrepreneurs' competences scored close to these skills.

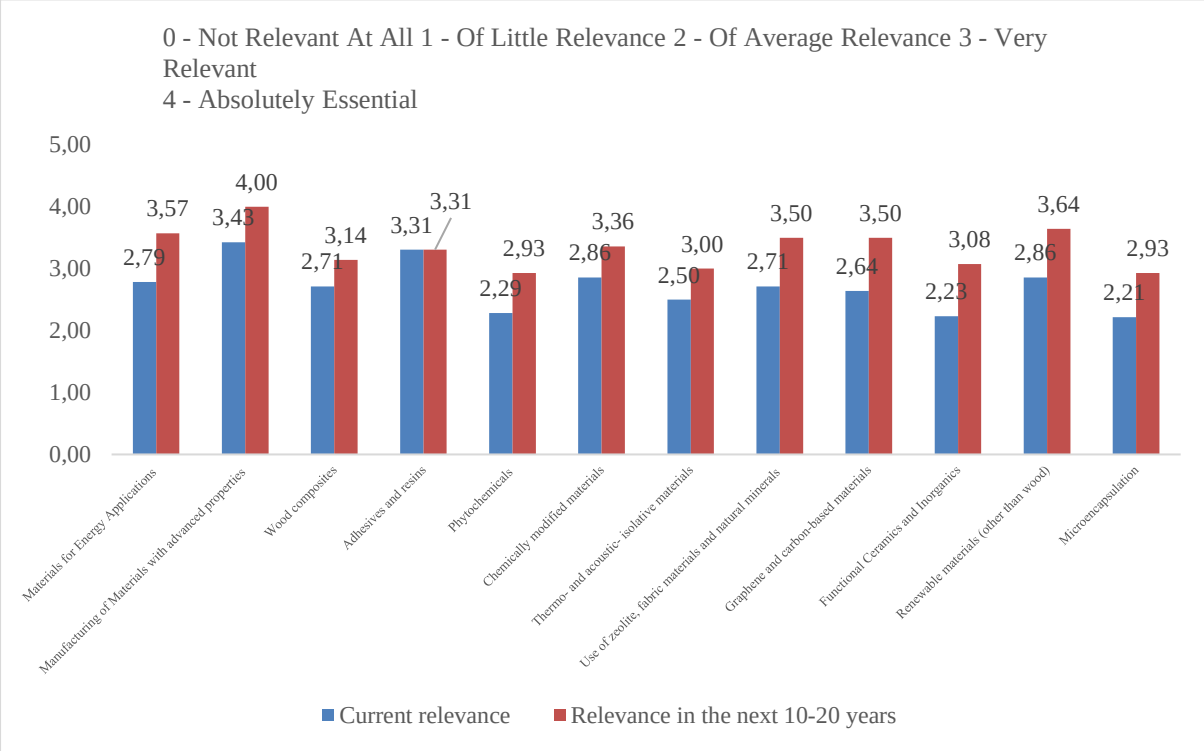

Figure 5. *Importance and relevance of skills to the business/work related to the advanced materials*

Source: Authors' own work

5. CONCLUSION

KETs represent the future of industry policies since they provide the basis for innovation. In Croatia, the opportunities they offer in boosting economic development and the ways to integrate KETs more strongly into the economy have been improperly explored. The research findings presented in this paper show that with regard to general skills, in order to make greater use of the opportunities that KETs provide, innovation management, communication and presentation skills, user-centred competences, and safety on job should certainly be strengthened.

Regarding the skills related to nanotechnology and according to the respondent's answers, currently all skills are of average importance, but in the middle term, they will be very relevant; finally, in the long term the skills related to nanotechnology will be essential.

Regarding biotechnology skills, the results show that the respondents consider at this moment that almost every biotechnology skill is of average relevance for a business or work. They consider that in the medium term these concepts will bear a higher relevance or even that they will be essential, especially in the case of industrial technologies for the production of biotechnological products, waste treatment and bioremediation and decontamination, and energy production from biological sources (bioethanol, methane, biogas); properties, wood composites, use of zeolite, fabric materials and natural minerals (in food, waste treatment, environmental protection, air pollution, *etc*.), and graphene and carbon-based materials. Most of the skills were pointed out as very relevant in the medium and long term.

The main conclusion of the research is that KETs will play a crucial role in industry and other policies in the near future. Moreover, KETs require well educated and specialised workforce, so their inclusion in the educational system, especially VET, is recognized as a key success factor.

Due to the high relevance of KETs in the near future and opportunities they provide, it is important to include them not only in educational system, but also in companies. Even though Croatian scientists have a lot of experience related to KETs, the transfer of the knowledge and skills that would bring the achievements of nanotechnology, biotechnology and advanced materials into everyday practice and the contribution to the development of the economy is not sufficient. In the near future, it is crucial to include KETs in the education system, to provide adequate knowledge related to them and to transfer that knowledge to the Croatian economy. In that way, the potential KETs have could be fulfilled and sustainable economic development could be achieved.

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