The paper presents an innovative economy - bioeconomy and explains the role of geography education in its development. The aim of the bioeconomy is to develop low-emission economies focused on developing the primary sector (agriculture, fishing, forestry), food security and sufficiency, encouraging the use of biomass in industry, protecting biodiversity and the environment (EUROPEAN COMMISSION, 2012). The shift from the traditional linear model of economy to the bioeconomy entails a move away from fossil resources and toward bio-renewable resources as well as a transition from a linear to a circular economy. Alongside entrepreneurs, the government/policies, scientific institutions, and international cooperation, formal, non-formal and informal education of every stakeholder in this economic area plays a key role in the development of the bioeconomy. The primary goal of this paper is to emphasize the role of geography education in and for the development of circular economy (bioeconomy), which is an aim of the Republic of Croatia defined by Development Direction 3, “Green and Digital Transition” (NATIONAL DEVELOPMENT STRATEGY 2030, 2020.). The secondary objectives of this paper are to analyse general theoretical features of the bioeconomy as well as employment and turnover structure in the EU bioeconomy sectors, with a special emphasis on the situation in the Republic of Croatia. The results of the work show that the Croatian bioeconomy is only in the initial cycle of its development. The Geography curriculum for primary schools and grammar schools (2019) contains a significant number of educational outcomes that concern energy sources, climate and climate change, ecosystems, biodiversity and the development of smart cities. Adopting these outcomes may contribute to the acquisition of competencies necessary for the development of new approaches of more innovative economies. The research was conducted using quantitative and qualitative methods. The analysis of the curricular content, especially the elaborations of outcomes geared toward a further development of the bioeconomy, is the basis for shaping professional development training for geography teachers to enable a more innovative and efficient management of the learning and teaching of these contents.
INTRODUCTION

The development of the global economy in the second half of the 20th century and onward has been defined by growth and intermittent crises. This growth has had positive as well as negative consequences, such as environmental pollution, climate change, biodiversity loss, and geopolitical tensions. Human activities and the world economy have had a major impact on the environment. However, the growing awareness about planetary ramifications has created a push for a transition toward a sustainable economy or sustainable development. As a concept, sustainable development is being progressively supplanted by the terms ‘bioeconomy’ or ‘bio-based economy’. As a relatively new approach with staunch advocates, bioeconomy is an economy based on innovative methods that replace fossil sources with intelligent and efficient bio-based materials and processes (Schlaile, Urmetzer, 2019).

The European Commission adopted a strategy\(^1\) to direct the European economy toward a bioeconomy or ‘a sustainable economy that uses resources with the aim to diminish the need for new resources and replace fossil carbon with renewable carbon from biomass’ (Kulišić, 2020., 5). The aim of the European Bioeconomy Strategy is to develop a more innovative, efficient, and competitive society that reconciles food security with the sustainable use of renewable biological resources for industrial purposes, while ensuring environmental protection (European Commission, 2012). In 2019, the EU adopted the Green Deal, a new growth strategy that aims to transform the continent into a climate-neutral, fair, and prosperous society with a modern, resource-efficient, and competitive economy (Europska Komisija (2019).

One of the national development directions of the Republic of Croatia – Development Direction 3, Green and Digital Transition – advocates the bioeconomy and circular economy. ‘The green and digital transition will be fostered by making a switch to clean energy, supporting green and blue investments, strengthening food self-sufficiency, establishing a circular economy, adapting to climate change, preserving and restoring ecosystems and biodiversity, and developing sustainable and smart mobility and connectivity’ (Nacionalna Razvoja Strategija 2030, 2020., 4).

\(^1\)The Bioeconomy Strategy and Action Plan supports three key areas: developing new technologies and processes for the bioeconomy; developing markets and competitiveness in biomass-based sectors; promoting intersectoral cooperation between policy-makers and stakeholders (Kulišić, 2020.).
The uneven global economic development, climate change challenges, biodiversity loss, and the ever-escalating consumption of resources call for a change of the status quo in labour, business, management, and education. ‘The challenge of sustainable development and participation in a responsible valuation of natural resources that will not irreversibly destroy the environment cannot be understood without geography’ (KURIKULUM GEOFRAFIJE ZA OSNOVNE ŠKOLE I GIMNAZIJE, 2019., 2). Pre-tertiary and tertiary education in geography may contribute to the development of the bioeconomy through instructional contents taught at the primary and secondary levels as well as its position relative to other subjects, cross-curricular topics, and curricular areas (KURIKULUM GEOFRAFIJE ZA OSNOVNE ŠKOLE I GIMNAZIJE, 2019.).

The primary goal of this paper is to analyse the role and potential of pre-tertiary geography education in and for the development of the bioeconomy and circular economy, which is the aim of the Republic of Croatia defined by Development Direction 3, ‘Green and Digital Transition’ (NACIONALNA RAZVOJA STRATEGIJA 2030, 2020.). The secondary goals of this paper are to analyse the general theoretical features of the bioeconomy as well as employment and turnover structure in the EU bioeconomy sectors, with a special emphasis on the situation in the Republic of Croatia. The key topics of the EU Bioeconomy Strategy are: food security, sustainable management of natural resources, reducing dependence on non-renewable resources, climate change – mitigation and adaptation, and creating jobs and maintaining European competitiveness. The role and potential of education in geography are analysed in accordance with these key topics.

OVERVIEW OF SELECTED RESEARCH

According to H. S. Gordon (1954), the bioeconomy has its roots in the research on fishery economics conducted by the Russian biologist F. I. Baranoff at the beginning of the 20th century. In the 1970s and 1980s, Nicholas Georgescu-Roegen was the first to envision the bioeconomy as a theoretical possibility and influenced the study and structure of environmental economy through his idea of growth (GEORGESCU-ROEGEN, 1975.). Georgescu-Roegen considered that the term defined a specific challenge faced by the human society: man, like every living creature, must fight against the law of entropy. According to him, technology augments the biological human body and allows for a broader scope of action (VIVIEN ET AL., 2019.). Whereas the initial conception had a philosophical bend, at the end of the 20th century, the bioeconomy evolved into a scientific concept. Biotechnology, as the core of bioeconomy, is based on technoscience and a new industrial paradigm (PATERMANN, AGUILAR, 2018.). The Organization for Economic Co-operation and Development (OECD) pioneered this second
interpretation by analysing the concept from the perspective of biological sciences that may help solve our pressing issues (mitigating climate change, improving health conditions and quality of life). Agricultural biotechnology boosts crop productivity, and biotechnology has a significant positive effect on economic productivity (VIVIEN ET AL., 2019.; OECD. 2009.).

Today, the common interpretation refers to bioremediation processes, which are applied by the European Commission in the areas of agriculture, forestry, fishing, as well as chemistry and biotechnology. Bioremediation is at the heart of the ecological transformation of biomass feedstocks (VIVIEN ET AL., 2019.; EUROPSKA KOMISIJA, 2012., 2018.; LONDO, MEEUSEN, 2010.).

The bioeconomy stands for a shift from a largely fossil fuel-based economy to a more efficient economy that is based on renewable resources and raw materials produced through a sustainable use of land and water ecosystem services (BENNICH, BELYAZID, 2017.). The bioeconomy entails the production of renewable biological resources and the transformation of these resources and waste flows into value-added products, such as food, animal feed, bio-based products, and bioenergy (VIVIEN ET AL., 2019.; EUROPSKA KOMISIJA, 2012., 2018.). Alongside entrepreneurs, the government/policies, scientific institutions, and international cooperation, formal, non-formal, and informal education/learning of every stakeholder in this economic area plays a key role in the development of a bioeconomy.

Owing to active contributions from various scientific disciplines, such as agronomy, environmental science, biotechnology, nanotechnology, and the IT, the bioeconomy has a major innovation potential (RAJH, 2017.). The bioeconomy is an innovative economy with low gas emissions focused on developing the primary sector (agriculture, fishing, forestry). Other goals of the bioeconomy are food security and sufficiency, the sustainable industrial use of renewable biological resources, as well as preserving biodiversity and environmental protection (EUROPSKA KOMISIJA, 2012., 2018.). Bioeconomy is often synonymous with green economy. A green economy goes beyond bio-products and energy production and is concerned with all renewable energy sources, ecological modes of production, recycling processes, and spotlighting socially acceptable economic activities; as such, it represents a more comprehensive approach pristup (BIOEKONOMIJA I ŠUMARSKA POLITIKA, 2, 2015). The circular economy is a building block of the bioeconomy. It is a multi-stage, closed-loop flow of raw materials, matter, and energy that is restorative and regenerative by design and purpose.

The importance of geographic science for the bioeconomy and the related socio-technical transition (STT) has been discussed extensively over the past decade, with a focus on the study of space, spatial relations, and energy flows (CALVERT ET AL., 2017.; MURPHY, 2015.; HUBER, 2015.; NEVILLE, DAUVERGNE, 2012.; SMITH ET AL., 2010.). In the early phase,
environmental economic geography tried to explain the bioeconomy as a collaboration between STT areas and geography (Calvert, 2016; Huber, 2012; Birch, Tyfield, 2013.). Energy geography has explored socio-environmental relations and the application of alternative low-carbon energy sources, especially biofuels and biomass. These energy sources pose a challenge to forest ecosystems conservation, especially in the north of Europe (Lovrić et al., 2020.). As an interdisciplinary science, geography approaches these issues from four multisectoral perspectives. These perspectives are the social analysis of spatial relations, geopolitics and geoeconomics in global trade flows, especially energy trade, the role of geography in STT, and the introduction of new technologies, such as GIS (Anejionu et al., 2020; Nøstebø et al., 2020; Kurka et al., 2012; Haddad, Anderson, 2008.).

METHODS

The selection and interpretation of literature and sources raised the following research questions: What are the features of the paradigm shift from a linear to a circular economy? Have there been any significant advances in the evolution of a bioeconomy in the Republic of Croatia over the last ten years? Does the Geography curriculum for primary and ‘gimnazija’” secondary schools include learning outcomes that correlate with the key topics of the EU Bioeconomy Strategy?

The research tested following hypotheses:

- A paradigm shift from a linear to a circular economy supports sustainability.
- Given that the bioeconomy in Croatia is in its early stages, education will play a major role in its future development.
- The primary and secondary school curriculum for Geography is a good starting point for education about sustainability and the bioeconomy.

The research was conducted using quantitative and qualitative methods as well as comparative and descriptive methods. The theoretical framework of the bioeconomy and circular economy was defined using comparative and descriptive methods. Quantitative methods (descriptive statistics) were used to analyse selected variables representing the size of bioeconomies in the EU member states (EU-28) and the Republic of Croatia (2017 total turnover and added value) as well as employment by bioeconomy sector in 2008 and 2017. Qualitative methods were used to analyse the content of the primary and secondary school curricula for Geography based on keywords of its learning outcomes. Learning outcomes associated with the EU Bioeconomy Strategy objectives were highlighted. The results of the curricular content analysis are a starting point for creating guidelines for effective and efficient
teaching and learning about bioeconomy principles in Geography classes and related subjects. Only effective education, especially in Geography, can prepare young people to successfully address the 21st century challenges.

RESULTS AND DISCUSSION

Paradigm shift – from linear to circular economy

A sustainable bioeconomy is key to combating climate change and land and ecosystem degradation. The shift from the traditional linear model of the economy to a bioeconomy entails a move away from fossil resources and toward bio-renewable resources as well as a transition from linear to circular economy. In the linear economy, waste is released into the environment as a by-product of the production process. The linear economy is based on the principle of ‘take – produce – use – throw away’ and assumes an unlimited and easy access to material resources. The central tenet of a circular economy is creating a closed loop of production and consumption with a minimal inflow of new materials and waste generation. Unlike the linear model, the founding principle of the circular economy is ‘reduce – reuse – recycle – redesign – remanufacture – recover’. The circular economy stands out as a potential solution for a sustainable economic development and is an integral part of the bioeconomy. It engenders a multi-stage, closed-loop flow of raw materials, matter, and energy (ANDABAKA ET AL., 2018.; ANDABAKA, 2018.; FRANKLIN-JOHNSON ET AL., 2016.). It is an industrial economy that is restorative and regenerative by purpose and design (URL 1). A key principle of the circular economy is: waste is food. All materials and products that have reached the end of their useful life become raw materials for the production of new goods. The main governing principle of the circular economy is working toward zero waste.

In its early stages, the circular economy was based on the concept of the 3 Rs (reduce – reuse – recycle), but this has now been expanded to 6 Rs (reduce – reuse – recycle – redesign – remanufacture – recover) (JAWAHIR, BRADLEY, 2016.). The global economy has been moving away from the linear production model and embracing a circular model that has a lower impact on the environment, improves supply security, facilitates innovation, and creates new jobs.

This transition requires interconnectivity between all key elements of the system. The initial interconnectivity system was based on a triple helix model, which explicitly stressed the importance of higher education for innovation. According to this model, the focus of the economy is on the production of knowledge and innovation, making it compatible with the knowledge economy. The addition of culture and society to science, politics, and economy and
the involvement of the public, non-governmental organizations, the media, and cultural institutions has given rise to a quadruple helix model, which requires cooperation with the knowledge society for a sustainable development of the knowledge economy. In addition to political and state rights and freedoms, consideration should be given to the impact on the natural environment or *space* as the fifth element in the so-called quintuple helix model, which calls attention to the need for a socio-environmental transition of society and economy in the 21st century (Fig. 1).

![Quintuple Helix model](image)

**Slika 1. Quintuple Helix model – naglasak na prirodni okoliš (prostor)**

**Figure 1 Quintuple Helix model - emphasis on the natural environment (space)**

Nature is seen as an endless source of ideas and processes, so the aim is to use biomimetics to try to imitate nature’s best solutions and apply them in production cycles. Industrial ecology has long been promoting a circular system that uses waste as a raw material or energy source. The Kalundborg symbiosis has been an example of a successful circular economy for almost 50 years (ŠILJKOVIĆ, 2011.).

Shifting the paradigm from linear to circular economy, the interconnectivity between all key elements of the system, and adopting an ecologically sensitive quintuple helix model (Fig. 1) may promote the sustainability of the system, thus confirming the first hypothesis presented in this paper.
BIOECONOMY IN THE EUROPEAN UNION AND THE REPUBLIC OF CROATIA – SITUATION AND PERSPECTIVES

In 2017, the indicators of the size of the bioeconomy in the EU member states (EU-28) were the EUR 2,454 billion turnover and EUR 685 billion added value. The total employment was 18.6 million (9% of total persons employed). Based on the employment (RONZON ET AL., 2020.; PIOTROWSKI ET AL., 2018.), Agriculture had the largest share of workers among all bioeconomy sectors. This was followed by the employment in the following sectors: food, beverage, and tobacco; wood and furniture production; bio-based textiles; paper; forestry; bio-based chemicals, plastics, and bags; the smallest employment share (less than 1% of persons employed) was in fisheries and aquaculture, liquid biofuels, and bio-based electricity (URL 2) (Fig. 2).

In 2017, the share of agricultural workers in total employment in the bioeconomy was 52% (3 percentage points less than in 2008). In 2017, the food, beverage, and tobacco sector had a 3.8 percentage point increase in employment share compared to 2008, but wood and furniture production and bio-based textiles recorded a drop in employment. The employment shares in other industries either rose slightly or stagnated (Fig. 2). In 2017, the index of change in total employment in the bioeconomy was 87.9 when compared to 2008 figures (whereas total employment in all activities was 102). Looking at individual sectors, almost every sector had a drop in employment except forestry, which had a 6.7% increase and the food, beverage, and tobacco production sector, which had a slight increase of about 2.5%. The biopower production sector had the most significant employment growth during the observed period, 262.1%. According to Kuljišić (2020.), this growth was a result of subsidies for energy generation from renewable resources in the gross final energy consumption in the EU until 2020 (RONZON ET AL., 2020.). According to EUROSTAT data (URL 3), in 2017, the total unemployment rate increased by 0.9 percent compared to 2008 figures. Due to the effects of the global financial crisis and the resulting chain of consequences, total unemployment rose between 2008 and 2014, but has been on the decline since. However, in 2017, 19 EU member states still had higher unemployment that in 2008.

---

3 EU-27: 17.5 million employees.
In contrast to the shrinking employment over the observed period, bioeconomy sectors experienced a turnover growth of 16.1%. This growth was greater in biomass processing than in biomass production. This may be explained by the increase in productivity and a more significant employment in the more labour-intensive sector of biomass production (agriculture). Sectors with the highest respective turnovers were food, beverage, and tobacco production (EUR 1.241 billion) and agricultural production of biomass (EUR 449 billion), which alone accounted for 68.9% of the total turnover in the EU-28 bioeconomy in 2017. Among bioeconomy sectors, turnover increase was recorded in bio-based electricity (251.4 %), liquid biofuels (41%), and bio-based chemicals, plastics, and bags (25.4 %). Between 2008 and 2017, biopower production had the greatest turnover growth, but this still accounted for only 0.9% of the total EU bioeconomy turnover in 2017 (Tab. 1).
Like other EU member states, the bioeconomy of the Republic of Croatia also had the greatest employment in agriculture and food, beverage, and tobacco. This was followed by the wood and furniture production, forestry, bio-based textiles, fisheries and aquaculture, and paper sector. As was the case in other EU countries, the liquid biofuels and bio-based electricity sectors had the lowest employment share (less than 1% of persons employed) (Fig. 3).

In 2017, the share of agriculture sector in employment was 42.6%, which was about 10 percentage points less than in 2008. The food, beverage, and tobacco sector had an 8.7%
employment growth in 2017 compared to 2008. The share of the labour force employed in *wood and furniture production* also increased (by three percentage points). *Paper, bio-based chemicals and plastics and bags, liquid biofuels and bio-based electricity* sectors had minor increases in employment or stagnated, whereas employment dropped in other sectors in 2017 compared to 2008 (Fig. 3). Compared to 2008, in 2017, the index of change in total bioeconomy employment was 62.2, meaning that the number of workers decreased by 37.8%, which was significantly higher than the EU-28 average. Looking at sectors individually, employment decreased in almost all sectors except in *paper, bio-based chemicals, plastics and bags, and bio-based electricity*, which had the greatest growth both in the Republic of Croatia and in the EU-28. The decrease in bioeconomy employment in Croatia may be explained by general trends in its economy. Between 2008 and 2017, the EU-28 saw a small rise in total employment (employment index was 102), whereas in the same period, Croatia recorded a decline in total employment (employment index was 95.6, making it one of the six countries with the largest employment decline). In addition to the declining employment rate and aging population, bioeconomy employment is also affected by the emigration structure of Croatia’s population. The strength of influence of individual factors (the cause of employment decline in general and in the bioeconomy) should be investigated and determined in a separate paper.

---

4 Portugal, Lithuania, Bulgaria, Romania, and Latvia had a larger employment decline.
In 2017, the Croatian bioeconomy generated EUR 11.3 billion turnover and EUR 3.4 billion added value, which was less than 1% of total turnover and less than 1% of added value of the EU-28 bioeconomy. ‘The average productivity of the Croatian bioeconomy is below the EU-28 average: EUR 13,000 added value per worker and EUR 41,000 turnover per worker’ (KULIŠIĆ, 2020., 15). In addition to decreasing employment, in 2017, bioeconomy sectors also experienced a 3.2% turnover decrease compared to 2008. This was below the EU-28 average, which had a turnover increase.

Bioeconomy sectors with the largest turnover share were food, beverage, and tobacco (50.4%), followed by agriculture (21.2%) and wood and furniture production (11.1%). Development prospects rest on the development of sectors that had an increase in turnover in
2017 compared to 2008, namely *bio-based electricity, paper, bio-based chemicals, plastics, and bags*, and *wood and furniture production* (Tab. 2).

**TABLICA 2. Promet po sektorima u bioekonomiji u Republici Hrvatskoj 2008. i 2017. godine**

**TABLE 2 Turnover by sectors in the bioeconomy in the Republic of Croatia in 2008 and 2017**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poljoprivreda / Agriculture</td>
<td>3,288.4</td>
<td>2,398.2</td>
<td>72.9</td>
<td></td>
</tr>
<tr>
<td>Šumarstvo / Forestry</td>
<td>358.6</td>
<td>354.5</td>
<td>98.9</td>
<td></td>
</tr>
<tr>
<td>Ribarstvo i akvakultura / Fisheries and aquaculture</td>
<td>201.5</td>
<td>299.8</td>
<td>148.8</td>
<td></td>
</tr>
<tr>
<td>Hrana, piće i duhan / Food, beverage and tobacco</td>
<td>5,699.5</td>
<td>5,696.4</td>
<td>99.9</td>
<td></td>
</tr>
<tr>
<td>Bio bazirani tekstil / Bio-based textiles</td>
<td>518.8</td>
<td>431.5</td>
<td>83.2</td>
<td></td>
</tr>
<tr>
<td>Proizvodnja drva i namještaja / Wood and furniture production</td>
<td>1,000.7</td>
<td>1,259.4</td>
<td>125.9</td>
<td></td>
</tr>
<tr>
<td>Papir / Paper</td>
<td>241.4</td>
<td>366.9</td>
<td>152.0</td>
<td></td>
</tr>
<tr>
<td>Bio bazirane kemikalije, plastika i vreće / Bio-based chemicals, plastics and bags</td>
<td>359.3</td>
<td>465.7</td>
<td>129.6</td>
<td></td>
</tr>
<tr>
<td>Tekuća biogoriva / Liquid biofuels</td>
<td>7.6</td>
<td>0.5</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>Bio bazirana električna energija / Bio-based electricity</td>
<td>1.1</td>
<td>33.6</td>
<td>2,947.3</td>
<td></td>
</tr>
<tr>
<td><strong>Ukupno promet / Total turnover</strong></td>
<td><strong>11,676.9</strong></td>
<td><strong>11,306.7</strong></td>
<td><strong>96.9</strong></td>
<td></td>
</tr>
</tbody>
</table>

Izvor / Source: URL 2

Based on the above indicators, we may conclude that the Croatian bioeconomy is still in its infancy, but shows good potential, especially in the sectors that had turnover growth. Bearing in mind the Croatian development directions from strategic documents such as the 2030 *National Development Strategies* which involve the bioeconomy and circular economy, education and the application of the quintuple helix model may play a major role in the upcoming period. This confirms the second hypothesis of this paper.
THE SOCIAL TRANSITION TOWARD THE BIOECONOMY CANNOT SUCCEED WITHOUT CERTAIN STRUCTURAL AND CULTURAL CHANGES AIMED AT EDUCATIONAL INSTITUTIONS IN SOCIETY AS A WHOLE (SOTIGU ET AL., 2020.). THE GOAL IS TO DESIGN A (PRE-)TERTIARY CURRICULA THAT CAN PROVIDE FORMAL EDUCATION TO COMPETENT WORKERS IN THE UPCOMING BIOINDUSTRY.

However, judging from the current school curricula, the education system seems to be at odds with the bioeconomy. On the one hand, students’ education regarding this economy sector is lacking, and on the other, there are no training opportunities for the current labour force to improve and broaden their skills and knowledge. However, Croatia is not different from other countries in this regard (SOTIGU ET AL., 2020.).

The majority of European countries are progressively shifting their focus toward the STEM (science, technology, engineering, mathematics) field as a key component in overcoming this conflict. The concept of bioeconomy can be incorporated into any component of STEM education, especially general education subjects (biology, chemistry, geography) as well as vocational education that covers recycling, recovery, disposal technologies, and writing project documentation.

Throughout pre-tertiary education, the concept of bioeconomy is included in the educational process at three complementary levels (HAKOVIRTA, LUCIA, 2019.). At schools, the bioeconomy is taught formally using traditional teaching methods, along with the acquisition of certificates and licenses.

Students can learn about the bioeconomy in informal settings as part of continuous professional development at various conferences, professional meetings, seminars, and in training courses. Informal education is the most liberal form of education, as well as the riskiest, since it stems from students’ spontaneous interest and manifests itself through conversation, research, and experiments (HAKOVIRTA, LUCIA, 2019.). Games, extracurricular and after-school activities are part of informal learning. Online learning enables students to communicate virtually and exchange knowledge and skills they have acquired in seminars, summer schools, through field work or independently, by working on case studies (SACCHI ET AL., 2021.).

Considering STEM fields, informal and non-formal learning includes visits to museums, galleries, libraries, industrial plants, infrastructure facilities related to the bioeconomy, such as landfills, recycling centres, or water treatment plants, plant nurseries, etc. This teaching method is normally readily available to urban student populations, but may pose a challenge when
working with marginalized and vulnerable groups (special needs students, low socioeconomic status students) and students with poor school infrastructure. However, these are key areas in the development of informal learning (Hakovirta, Lucia, 2019). During the pandemic and after Banovina earthquake of December 2020, students from remote rural areas were not only unable to attend classes in situ but were also often unable to participate in online classes due to infrastructural damage.

Since not every form of learning can be applied to every student, stimulating students’ interest in the STEM fields will require striking a balance among the three approaches. Another weakness of the education system is insufficient cooperation among students from different schools at the local and regional level. Apart from school competitions, there are negligible opportunities for cooperation on joint projects in the local community. Schools remain both horizontally and vertically isolated. STEM sciences enable greater communication and collaboration among schools concerning analyses of local environments as well as research in the area of biology (forest ecosystems in a settlement/municipality/region, park areas, urban gardens), chemistry (industry in a settlement, municipality, or region, waste...), and physics (analysis of telecommunication networks in a settlement, municipality, city). In addition to acquiring professional knowledge, this kind of cooperation also provides opportunities to develop social skills for both students and teachers, who often do not interact with each other (except at professional meetings and privately) to serve the common interest of their schools and communities.

A new Geography curriculum has been introduced in the 2019-2020 school year to the first generation of fifth graders in primary schools and first year students in secondary schools. In 2020-2021, it was also introduced in the sixth grade of primary school and the second and third grades of secondary school. Starting from 2022-2023, all primary school students will receive instruction based on the subject curriculum, whereas the new Geography curriculum will be fully implemented in all years of the ‘gimnazija’ secondary schools from the 2021-2022 school year.

When we analyse the content of learning outcomes from the Geography curriculum based on the key topics of the EU Bioeconomy Strategy, we may conclude that there are sound conditions in place for relevant education in each of these areas (Tab. 4).
### Table 3: The relationship between educational outcomes from the Geography curriculum and key topics of the EU Bioeconomy Strategy

<table>
<thead>
<tr>
<th>Ključna tema EU Strategije Bioekonomije / Key topic of the EU Bioeconomy Strategy</th>
<th>Odgojno-obrazovni ishod u kurikulumu Geografije / Educational outcome from the Geography curriculum</th>
<th>Razrada odgojno-obrazovnih ishoda (odabrani sadržaji) / Elaboration of educational outcomes (selected content)</th>
</tr>
</thead>
</table>
| 1. Sigurnost u opskrbi hranom / Food security | GEO SŠ C.4.1. Učenik istražuje važnost poljoprivrede te analizira neravnomjernu dostupnost hrane u svijetu. / GEO Secondary School C.4.1. Students investigate the importance of agriculture and analyse unequal food distribution in the world. | – analizira prirodno-geografske i društveno-geografske čimbenike koji utječu na razvoj i mogućnosti različitih oblika poljoprivredne proizvodnje / analyse the natural geographical and socio-geographical factors that influence the development and potentials of various forms of agricultural production;  
– uspoređuje najveće proizvođače i izvoznike/uvoznike glavnih prehrambenih poljoprivrednih proizvoda prema statističkim podacima FAO-a / compare the largest producers and exporters/importers of the main agricultural crops according to FAO statistics;  
– analizira globalnu dostupnost hrane i načine rješavanja problema pothranjenosti i gladi u svijetu / analyse the global food availability and solutions to the global problem of malnutrition and hunger;  
– raspravlja o primjeni suvremenih tehnologija u proizvodnji hrane / discuss the application of modern technologies in food production, and  
– raspravlja o održivoj poljoprivredi / discuss sustainable agriculture. |
| 2. Održivo gospodarenje prirodnim resursima / Sustainable management of natural resources | GEO SŠ B.C.2.8. Učenik analizira strukturu, rezerve i prostorni raspored energetskih izvora i mineralnih sirovina, prepoznaje važnost sirovina i energije za gospodarski razvoj. / GEO Secondary School BC2.8. Student analyse the structure, reserves, and spatial distribution of energy sources and mineral feedstocks, recognize the importance of resources and raw materials,  
– pomoću geografske karte analizira prostorni raspored neobnovljivih i obnovljivih izvora energije / use a geographical map to analyse the spatial distribution of non-renewable and renewable energy sources;  
– argumentirano raspravlja o važnosti i obvezi korištenja obnovljivih izvora energije te zauzima stav o njihovu korištenju / argue the importance and responsibility of using renewable energy sources and take a position on their use; |

---

**Tablica 3.** Povezanost odgojno-obrazovnih ishoda u kurikulumu nastavnog predmeta Geografije i ključnih tema EU strategije bioekonomije

**TABLE 3** The relationship between educational outcomes from the Geography curriculum and key topics of the EU Bioeconomy Strategy
| 3. Smanjenje ovisnosti o neobnovljivim resursima / Reducing dependence on non-renewable resources | importance of was material and energy for economic development. | – analizira energetske potencijale, proizvodnju i potrošnju električne energije u zavičaju i Hrvatskoj / analyse energy potentials, electricity production, and consumption in their region and in Croatia, and
– uspoređuje proizvodnju i potrošnju energije u Hrvatskoj s odabranim državama u Europi i svijetu / compare energy production and consumption in Croatia with selected countries in Europe and the world. |
| GEO OŠ C.6.4. Učenik navodi i opisuje prirodna bogatstva, sirovine i izvore energije, navodi vrste onečišćenja i mjere zaštite te objašnjava važnost selektiranja otpada. / GEO Primary School C.6.4. Students list and describe natural resources, raw materials, and energy sources, list types of pollution and prevention measures and explain the importance of waste sorting. | – navodi i opisuje prirodna bogatstva, sirovine i izvore energije / list and describe natural resources, raw materials, and energy sources;
– razlikuje obnovljive od neobnovljivih izvora energije i objašnjava utjecaj njihova korištenja na okoliš / distinguish between renewable and non-renewable energy sources and explain their impact on the environment;
– navodi primjere onečišćenja okoliša na lokalnoj i globalnoj razini / list examples of environmental pollution at the local and global level;
– opisuje važnost selektiranja i recikliranja otpada / describe the importance of waste sorting and recycling;
– navodi moguće mjere zaštite od onečišćenja / list pollution prevention options;
– samostalno ili u skupini istražuje u zavičaju vrste onečišćenja / investigate types of pollution in their region, independently or in groups, and
– analizira i prezentira prikupljene podatke te raspravlja o mogućim mjerama zaštite / analyse and present collected data and discuss prevention options. |
| GEO OŠ C.A.B.8.1. Učenik analizira prirodno-geografska obilježja polarnih područja, izdvaja specifične uvjete života i prilagodbe živih bića te objašnjava mogućnosti i ograničenja iskorištavanja njihovih prirodnih resursa. / GEO Primary School C.A.B.8.1. Students analyse natural geographic features of the polar regions, focusing on the | – navodi specifične klimatske uvjete polarnih područja i njihov utjecaj na tlo i živi svijet / list the characteristic climate conditions of the polar regions and their impact on the soil and the living world;
– razlikuje pojavne oblike leda na kopnu i u moru / differentiate between different ice forms on land and sea ice, and
– navodi primjere i objašnjava mogućnosti i ograničenja iskorištavanja prirodnih resursa polarnih područja / give examples and explain the possibilities and limitations of exploiting natural resources in polar regions. |
<table>
<thead>
<tr>
<th>Characteristic living conditions and adaptations of living organisms, and explain the options and limitations of exploiting their natural resources.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO ŠŠ C.B.3.1. Učenik analizira održivo upravljanje resursima mora i podmorja s primjerima iz svijeta i Hrvatske. / GEO Secondary School CB3.1. Students analyse sustainable management of sea and deep-sea resources with examples from the world and Croatia.</td>
</tr>
<tr>
<td>– opisuje iskorištavanje i mogućnosti iskorištavanja mora i podmorja kao izvora energije i hrane / describe legislation on sea and deep-sea exploitation and give examples from the world and Croatia;</td>
</tr>
<tr>
<td>– opisuje zakonsku regulativu u iskorištavanju mora i podmorja s primjerima iz svijeta i Hrvatske / describe the exploitation and exploitation options of the sea and deep sea as energy and food sources;</td>
</tr>
<tr>
<td>– objašnjava ekonomsku ulogu kontinentskog plićaka / explain the economic role of the continental shelf;</td>
</tr>
<tr>
<td>– analizira važnost offshore vađenja rudnoga bogatstva te opisuje glavna ograničenja i opasnosti / analyse the importance of offshore mining and describe the main limitations and hazards;</td>
</tr>
<tr>
<td>– analizira važnost i održivost morskoga ribarstva i marikulture / analyse the importance and sustainability of sea fishing and mariculture;</td>
</tr>
<tr>
<td>– opisuje obilježja i posljedice El Niña / describe the features and consequences of El Niño;</td>
</tr>
<tr>
<td>– objašnjava ekološku ulogu i vrijednost koralnih grebena i mangrova, njihovu ugroženost i potrebu zaštitu / explain the environmental role and value, endangered status, and need for the protection of coral reefs and mangroves, and</td>
</tr>
<tr>
<td>– objašnjava potrebu i mogućnosti zakonske zaštite dijelova mora i podmorja na primjeru Hrvatske / explain the need and options for legal protection of parts of the sea and deep-sea using Croatia as an example.</td>
</tr>
<tr>
<td>4. Klimatske promjene – prevencija i prilagodba / Climate change</td>
</tr>
<tr>
<td>GEO OŠ B.6.5. Učenik opisuje atmosferu i vrijeme, objašnjava najvažnije klimatske elemente, prikuplja i analizira podatke o vremenu te obrazlazi</td>
</tr>
</tbody>
</table>
| GEO OŠ B.A.7.1. Učenik analizira prirodno-geografska obilježja Europe i objašnjava njihov utjecaj na naseljenost i gospodarske aktivnosti. / GEO Primary School B.A.7.1. Students analyse Europe’s natural and geographical features and explain their impact on population density and economic activities. | obrazlaže utjecaj klimatskih čimbenika na klimu, uspoređuje najzastupljenije tipove klime s pomoću klimatskih dijagrama te navodi i opisuje pripadajuću vegetaciju / explain the effect of climate factors on the climate, compare the most common types of climates using climate diagrams, and list and describe the associated vegetation, and 
– objašnjava utjecaj prirodno-geografskih obilježja na naseljenost i gospodarstvo Europe s pomoću tematskih karata / explain the effect of natural geographic features on Europe’s population density and economy using thematic maps. |
| GEO OŠ B.8.5. Učenik klasificira klimatske tipove, opisuje njihova obilježja i povezuje ih sa živim svijetom. / GEO Primary School B.8.5. Students classify climate types, describe their features, and relate them to the living world. | – analizira i izrađuje klimatske dijagrame / analyse and create climate diagrams; 
– navodi glavne klimatske tipove prema Köppenovoj klasifikaciji / list the main climate types according to the Köppen classification; 
– opisuje njihova obilježja s pomoću klimatskoga dijagrama / describe their features using a climate diagram; |
| GEO SŠ B.1.3. Učenik objašnjava utjecaj klimatskih modifikatora na određene klimatske elemente koristeći se geografskim kartama i IKT-om. / GEO Secondary School B.1.3. Students explain the impact of climate modifiers on certain climate elements using geographic maps and ICT. | – objašnjava rasprostranjenost tipova klime s pomoću geografske karte / explain the distribution of climate types using a geographic map, and – opisuje pripadajući živi svijet / describe the associated living world. |
| GEO SŠ B.1.4. Učenik objašnjava uzroke i posljedice svih razina cirkulacije atmosfere s primjerima iz svijeta i Hrvatske koristeći se geografskim kartama i IKT-om. / GEO Secondary School B.1.4. Students explain the causes and consequences of atmospheric circulation at all levels with examples from the world and Croatia using geographic maps and ICT. | – objašnjava uzroke planetarne cirkulacije i objašnjava postanak planetarnih vjetrova / explain the causes of planetary circulation and the origin of planetary winds; – objašnjava postanak monsunskih vjetrova / explain the origin of monsoon winds; – objašnjava zračne mase i opisuje fronte / explain air masses and describe fronts; – objašnjava nastanak, razvoj i obilježja ciklone i anticiklone / explain the origin, development, and features of cyclones and anticyclones; – opisuje obilježja i kretanje tropskih ciklona / describe the features and movement of tropical cyclones; – analizira podatke iz tablica i grafičkih prikaza / analyse the data using tables and graphs; – obrazlaže utjecaj atmosfere, geografske širine, raspodjele kopna i mora, nadmorske visine, reljefa i morskih struja na klimatske elemente / explain the influence of the atmosphere, latitude, land and sea distribution, altitude, terrain, and sea currents on climate elements; – objašnjava geografsku raspodjelu temperature zraka, tlaka zraka i padalina na Zemlji s pomoću geografskih karata i IKT-a / explain the geographical distribution of air temperature, air pressure, and precipitation on Earth using geographic maps and ICT, and – objašnjava efekt staklenika / describe the greenhouse effect. |
GEO SŠ B.3.2. Učenik analizira promjene klime te argumentirano objašnjava utjecaj čovjeka na globalno zatopljenje. / GEO Secondary School B.3.2. Students analyse climate change and provide arguments for the human impact on global warming.

GEO SŠ B.3.3. Učenik analizira posljedice globalnoga zatopljenja te aktivnosti međunarodne zajednice u rješavanju toga problema. / GEO Secondary School B.3.3. Students analyse the consequences of global warming and actions of the international community to address this issue.

- navodi obilježja vremenskih nepogoda / list the features of natural disasters, and
- objašnjava tercijarnu cirkulaciju / explain tertiary circulation.

- navodi dokaze o promjeni klime tijekom geološke prošlosti i u instrumentalno doba / cite evidence of climate change in the geological past and in the modern measurement era;
- objašnjava efekt staklenika / explain the greenhouse effect;
- analizira podatke o glavnim stakleničkim plinovima u atmosferi i globalnoj temperaturi / analyse data on the impact of major greenhouse gases on the atmosphere and global temperature;
- objašnjava utjecaj čovjeka na emisiju stakleničkih plinova / explain human influence on greenhouse gas emissions;
- objašnjava promjenu klime kao prirodni i antropogeno uvjetovani proces / explain climate change as a natural and anthropogenically conditioned process;
- objašnjava utjecaj klimatskih promjena na život na Zemlji / explain the impact of climate change on life on Earth;
- objašnjava aktualne prirodno-geografske promjene do kojih dolazi zbog globalnoga zatopljenja / explain the current natural changes in geography that occur due to global warming;
- objašnjava moguće posljedice globalnoga zatopljenja, negativne (npr. invazivne vrste, klimatske migracije stanovništva, sukobi) i pozitivne (npr. nove poljoprivredne i turističke mogućnosti) / explain possible consequences of global warming, negative (e.g. invasive species, climate migrations, conflicts) as well as positive (e.g. new agricultural and tourism opportunities);
- navodi primjerе međunarodne aktivnosti usmjerene smanjenju čovjekova utjecaja na klimatske promjene / cite examples of international actions aimed at reducing human impact on the climate change, and
- uspoređuje i obrazlaže različite stavove država i organizacija u svijetu oko smanjenja emisije stakleničkih plinova / compare and
| 5. Radna mjesta i osiguranje konkurentnosti Europe / Creating jobs and ensuring Europe’s competitiveness | GEO SŠ B.2.7. Učenik analizira i uspoređuje različite pokazatelje razvijenosti na svim prostornim razinama. / GEO Secondary School B.2.7. Students analyse and compare various development indicators at all spatial levels. | explain different positions of countries and organizations globally regarding the reduction of greenhouse gas emissions. – analizira strukturu gospodarstva u zavičaju, Hrvatskoj, Europi i svijetu (prema udjelu zaposlenih i dohotku prema sektorima djelatnosti) / analyse the structure of economy in their region, Croatia, Europe, and the world (based on employment and income by economy sector); – uspoređuje važnost pojedinih sektora djelatnosti / compare the significance of different economy sectors, and – navodi, analizira i kritički raspravlja o gospodarskim i socioekonomskim pokazateljima razvijenosti / state, analyse, and critically discuss the economic and socioeconomic indicators of development. |

---

Izvor / Source: KURIKULUM NASTAVNOGA PREDMETA GEOGRAFIJA, (2019.)

As the first key topic, *food security* is covered by the GEO Secondary School C.4.1 as one of the outcomes in the fourth year of secondary school. Contents of the elaboration on the GEO Secondary School B.C.2.8 educational outcome in the second year of the ‘gimnazija’ secondary school ensure a basic understanding of the *sustainable management of natural resources*, another key topic of the EU Bioeconomy Strategy. Basic knowledge about the third key topic is ensured by the GEO Primary School C.6.4 educational outcome for the sixth grade of primary school. As the Geography education in subsequent grades of primary school is largely focused on the concept of sustainability as one of its four key concepts, other learning outcomes in primary school, e.g. in the eighth grade (GEO Primary School C.A.B.8.1) as well as the ‘gimnazija’ secondary school (GEO Secondary School C.A.B.3.1) also cover and contribute to the education on the third key topic. Students acquire knowledge and skills in the fourth key topic gradually and continuously. In the sixth grade of primary school, students acquire basic knowledge and skills regarding the climate in Croatia and on Earth (GEO Primary School B.6.5 outcome), then deepen this knowledge in the seventh grade using Europe as an example (GEO Primary School B.A.7.1 outcome), and continue to do so in the eighth grade, using examples from non-European continents (GEO Primary School B.8.5 outcome). They gain more complex knowledge in the first year of secondary school (GEO Secondary School B.1.3 and GEO Secondary School B.1.4 outcomes) and the most complex understanding follows in the third year, as part of the GEO Secondary School B.3.2 and GEO Secondary School B.3.3 educational outcomes. Students acquire knowledge about the fifth key Strategy
topic through a learning and teaching outcome in the second-grade Geography for secondary schools. The selected learning outcomes from the Geography curriculum corroborate that the curriculum is a stepping stone for an education on sustainability and the bioeconomy, thus confirming the third hypothesis of this paper.

A good foundation for an integrated approach to learning and teaching about the bioeconomy is laid by the cross-subject curriculum for Sustainable Development (KURIKULUM MEDUPREDMETNE TEME ODRŽIVI RAZVOJ, 2019). The purpose of teaching and learning about Sustainable Development as a cross-curricular topic is to train students for independent and responsible decision-making on issues important to them and society as a whole, as confirmed by its description, which claims that through ‘...practical work, students are encouraged to adopt behaviours such as using natural resources and energy, using locally produced food, rational waste management, using second-hand materials, active work and cooperation in the community.’ Teaching and learning about the cross-curricular topic Sustainable Development in mandatory and elective classes, homeroom, integrated, project, extracurricular, and field courses, as well as extracurricular activities stimulates the development of knowledge related to natural systems, the consequences of human actions, solidarity with other people, care for the environment, one’s own and others’ health, the ecosystem, and future generations (KURIKULUM MEDUPREDMETNE TEME ODRŽIVI RAZVOJ, 2019.).

In addition to educational policy documents that lay a foundation for learning contents, the training of geography teachers to use new approaches in planning and teaching classes and evaluating learning outcomes is also important. Although the COVID-19 pandemic has greatly affected the format of teacher professional development training, we may conclude that great attention has been paid to new approaches in learning and teaching over the last five years. In addition to professional conferences aimed primarily at geographers, there has been an increase in integrative training opportunities, such as the conference on the Scientific Approach to Learning and Teaching about Sustainable Development (URL 4). Topics with the keyword ‘sustainable development’ are also represented at academic conferences at the county-level and other structured and unstructured forms of professional training and professional development.

In order to implement bioeconomy principles in pre-tertiary education, future professional development opportunities should be built on international experiences, but also tailored to the practice in Croatia (KIRCHHERR, PISCICELLI, 2019.). We may expect effects similar to those experienced by other countries – where lecturers simultaneously teach and learn about sustainability (WU, SHEN, 2016., prema KIRCHHERR, PISCICELLI, 2019., 3; BRUMAGIM, CANN, 2012.; PERSONS, 2012.).
Stakeholders in geography education, as well as education in other subjects and areas, have a responsibility to help create a sustainability-based society – and Croatia has favourable conditions to make this happen.

ZAKLJUČAK

Mitigating negative consequences of contemporary development requires new approaches in economies at every level, from local to global. The bioeconomy is an innovative approach integrated into the development strategies of the European Union and Croatia. Taking into account the features, goals, and potentials of the bioeconomy, serious consideration should be given to laying the groundwork for its implementation in the modern economy as a way to achieve sustainability. The quintuple helix model of the functioning of key elements of economic systems supports sustainability of these systems. Employment in the bioeconomy accounts for 9% of total employment and is pivotal to meeting the objectives of key topics of the EU Bioeconomy Strategy. More than three quarters of these workers are employed in two bioeconomy sectors, agriculture and food and beverage production, laying an important foundation for the first key topic, food security. Croatian bioeconomy is in its infancy, and while still below the EU average, boasts attractive prospects. The development directions Croatia aims for, as defined in strategic documents such as the 2030 National Development Strategies, may accelerate the progress and facilitate realization of its potential. Education will have a major role in and responsibility for achieving these strategic guidelines, alongside other stakeholders. Geography education in primary and secondary schools based on the adoption of defined educational outcomes from the curriculum is in step with the strategic guidelines of the 2030 National Development Strategy as well as the key topics of the EU Bioeconomy Strategy and European Green Deal. Steady adaptation of learning outcomes highlighted in Table 4 through comprehensive geography education over the course of eight grades may create conditions and provide opportunities for young people in Croatia to contribute to the success of both the National Development Strategy and the European Green Deal. This will help establish geography as an interdisciplinary and multidisciplinary science that plays a significant role in education at every level, from primary to tertiary education, as well as in all forms of learning, from formal to lifelong learning.
IZVORI I LITERATURA / SOURCES AND BIBLIOGRAPHY


**Ružica Vuk made her scientific contribution** by participating in the drafting of the research paper, selecting research methods, designing the final research questions and hypotheses, writing the section on pre-tertiary geography education in the Republic of Croatia, the bioeconomy and the conclusion, as well as final content editing and formatting of all sections of this paper.

**Biljana Vranković made her scientific contribution** by collaborating on setting the methodology, research questions, and hypotheses, contributing to the theory review of the development of the bioeconomy, the quantitative and qualitative analyses of the scope of the bioeconomy in the EU member states (EU-28), and the comparative overview of educational outcomes from the Geography curriculum, as well as the final edit of the manuscript for the introduction, methodology, and part of the results and discussion section, namely Paradigm Shift – from Linear to Circular Economy, The Bioeconomy in the European Union and the Republic of Croatia – Situation and Perspectives.

**Željka Šiljković made her scientific contribution** by laying the groundwork for a multidisciplinary interaction between geography and bioeconomy and evaluating the scientific justification for the inclusion of geography and bioeconomy in the geography space. She made a contribution to the section on theory review of the paradigm shift from linear to circular economy and participated in the final edit of the entire paper.