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Computational skills in geosciences higher education system for the 21st century

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Abstract

There has been a lot of research worldwide on what the education of the future will look like. We are witnessing a growing number of indicators of the slow collapse of education as we know it. It is likely that higher education is approaching a major turning point. Thereafter, the speed and flexibility of adapting to global change will be the main determinants. Ubiquitous digitalisation, new trends, and sustainability will be the key concepts of business models in the future. Alongside computer skills, the new generations will need programming skills as well. The higher education system must take this task as seriously and urgently as possible. Without the mentioned knowledge and skills, it will be difficult for future employees to compete in the labour market and/or further professional career advancement. This article addresses the question of what the future directions of the geoscience education ought to be as the technology is evolving while datasets become richer. Hence, machine learning will have more success in the field. The application of computer and mathematical methods in geosciences, incorporated in the concept of computational geosciences, will determine the future of geology and related disciplines.

Keywords: geoscience, higher education, skills, job, computational science

1. Introduction

Times are challenging and completely unpredictable, but one thing is certain – human capital is the most valuable asset now more than ever. Another certainty relates to technological advances, specifically the ones that support digital and green transformation. Today's world teems with interesting new and innovative technologies and ways of working, with a direct contribution to the development of society. The three key concepts are reshaping the business world: recognizing new trends, reacting quickly, and applying digital thinking at all levels. Thanks to competition, the driving force behind the existing businesses should be a basic principle – always be one step ahead, think outside the box and set trends. But what about scientists? Students? Robots? Does it make sense to ask questions (respectively): how do you measure success? Does your teacher bring the surprise by classroom discussion and activity? All three categories (or entities) have something in common, and it is investment. Countries with large government spending on science and education programs have leading roles on the global stage. Chances are that you've probably heard of this mantra. However, many of us have no idea how long, difficult and tough journey it is. Even in affluent societies, there is still a long way to go. They have so many new potential projects, initiatives and partnerships in their plate, and it's been a real struggle to keep pace with such giants in terms of know-how, know-what, and know-why. Long ago, their citizens have realized the importance of focus on lifelong learning and openness to change.

Scientists bring their personal purpose into their work; science is their raison d'être. They understand very well the practical meaning of investments. One example is attending the conferences that have hefty prices. More and more, such events bring together science and business for dialogue on innovative ways to enhance productivity in the respective field, and investment as well. In fact, this is composed of the following: 1. investing in the science, 2. inventing the products (patents, publications, concrete products, etc.), 3. rising the scientometric indicators of success, 4. rising the investments, 5. developing the entire science and education system, 6. improving the entire physical landscape that makes people appreciative, and so on. Therefore, it deserves to say plain and simple: science is business.

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It is everywhere, in everything, for everyone. The biggest challenge is finding a way to stay competitive in the conditions of generally underpaid science, let alone schools and universities. Students should strive for excellence which should be the way of their daily work and thinking, yet many of them struggle financially. Both, scientists and students, operate in the global labour market where trends and needs are the same. Systematic monitoring of the scientific advancements should be one of their priorities, but that is hardly possible without investments in the development of technologies of the future. One of them is computers, mother of a hot topic discipline called computational science. Computational science is a discipline concerned with the design, implementation and use of mathematical models to analyse and solve scientific problems. Typically, the term refers to the use of computers to perform simulations or numerical analysis of a scientific system or process (**URL 1**).

When we talk about the geoscience, or earth science (i.e. the study of Earth), many things have changed in the discipline since 17th or 18th century, when it became its own entity in the world of natural science. It was the first science in human history, and almost everything we use comes directly or indirectly from Earth. Nowadays, climate change, the petroleum industry and mineral resources are perceived as the top priority fields in applied geosciences. In spite of the fact that nearly everything around us – from the mountains out our window to the cell phone in our hand to the water from our tap – is connected to geoscience (**URL 2**), geology is one of the most underrated and underappreciated sciences out there (**URL 3**). Many people find rocks boring, but geology is much more than studying rocks; earth scientists are at the forefront of addressing complex problems such as climate change, natural resource use, environmental degradation, and energy sustainability (**Medunić et al., 2016**; **URL 2**). Geologists are people who study earthquakes and break down this knowledge for everyone, and not only that, but they're some of the people who are doing research to find a solution (**URL 3**).

Orion (**2019**) elaborated the gap between the importance and relevance of the earth science to society and its low status in schools worldwide. According to the author, significant research efforts should be invested among the university geoscience researchers and professors to undertake a deep change at all levels of the university geoscience education programs by applying a new, holistic research agenda. The proposed change should include the integration of the following three subjects within the traditional university geoscience disciplinary courses: the earth systems approach, geo-ethics education, and the development of communication skills. The truth is that geoscience study programs in Europe face a serious challenge to attract students. **Mileusnić** (**2020**) presents an innovative teaching method that has become more recognized by US geoscience teachers compared with their European counterparts. It is called service learning with real science and engineering at its centre. It has the potential to raise the awareness of the study program and interest in geosciences in the wider society. The author described the service learning (or community-based learning) features; it is an educational approach that combines learning objectives with community service in order to provide a pragmatic, progressive learning experience while meeting societal needs. Student teams apply the structured knowledge and skills acquired in the academic course while developing a project that deals with a specific social problem. For example, risk management of earth-quake hazard has important social aspects. Helping in clearing rubble or supplying groceries after an earthquake is service, while measuring active faults in the field is learning. A review paper by **King** (**2008**) indicated that geoscience education would progress most effectively through the following aspects: 1/ extending geoscience learning to all children; 2/ educating teachers in effective implementation of new curriculum initiatives; 3/ evaluating the progress of the initiatives and using the results to refine them; and 4/ researching the whole process to demonstrate its effectiveness and to ensure wide dissemination on the basis of well-founded research findings.

By all means, geoscience education should adapt to the radically and rapidly changing world. We are facing energy transition, economic slowdown (degrowth), the rise of artificial intelligence and large data sets (big data). Western geoscience universities have already embraced “outside-the-box” thinking by creating new avenues for students in the geoscience workforce. Specifically, their programs offer non-geoscience majors supported by enough technical geoscience skills and adequate soft skills. With this in mind, the aim of this paper is to present some of the geoscience workforce skills, particularly computational ones that will remain in high demand in the decades to come.

2. Employment prospects in the geosciences

Geoscientists study the physical aspects of the Earth, such as its composition, structure, and processes, to learn about its past, present, and future. Their employment opportunities are expanding as natural hazards are more frequent and intense, coastal infrastructure is threatened from rising sea levels, food and water supplies are affected by warming climate, while global energy and resource needs should be met in a sustainable and environmentally responsible way. According to **Mosher and Keane** (**2021**), students who conduct quantitative analysis easily, apply critical thinking and problem-solving skills, manage and analyse large data sets, communicate effectively in a variety of formats, and work well in teams will likely succeed in the future work environment. The authors emphasize that students need to be prepared for changing workforce needs, including new careers and jobs that require the use of new technologies, strong quantitative and computational skills, data analytics and machine learning, interdisciplinary teamwork and problem solving. However, there are opponents who call it 'Nintendo' geology, an over-reliance on 3D mapping and visualization techniques; they complain that today's workforce lacks a knowledge base in four areas in particular – stratigraphy, structural geology, sedimentology and field geology (**Gewin, 2016**). The author concluded that despite financial shortages of all kinds, geoscience skills remain in great demand, even during difficult times (e.g. the low price of oil). According to **Geological Society of America** (**2016**), the interdisciplinary geosciences require the next generation of skilled geoscience workers to not only tackle the serious challenges in natural resource development and management, natural hazards mitigation, environmental protection, and ecosystem restoration, but also to apply integrative geoscience skills and knowledge to a host of related (civil and environmental engineering, environmental studies, agricultural sciences, atmospheric and ocean sciences, and life sciences) and seemingly unrelated (materials research, homeland security and emergency services, medicine, law, public administration, public health, and economics) fields. In a very optimistic tone, **Mosher et al.** (**2014**) point out that a large segment of the current workforce begins to retire, and geoscience jobs increase in number; hence, we will face a shortage of geoscientists for the future workforce. Therefore, the authors suggest a roadmap for the future undergraduate geoscience education by combining efforts of departments and programs, led by administrators, individual faculty innovators, geoscience professional societies, and industry (investment!). It shouldn't be difficult in educational settings (in affluent countries mostly) where technology is being used in new ways, including virtual experiences, flipped classrooms, blended learning, massive open online courses, and crowdsourcing of open education resources. Major advances have taken place in visualization and geospatial tools, generation and use of massive amounts of quantitative information (big data), and computational modelling, and simulation for both predictive capabilities and insight into processes and global-scale events. The authors conclude that undergraduate students must be prepared to use rapidly advancing technologies and big data in the future (**Mosher et al., 2014**).

3. Quantitative geosciences skills in the 21st century

Geosciences used to be largely descriptive back in the past. This is no longer true as they have become rather quantitative in the 21st century. As modern geosciences use equations, models, and numbers in conjunction with observations, maps, and words as fundamental tools for investigating the Earth, the geoscience workforce of tomorrow need to be prepared to meet the quantitative demands of industry, research, and education. However, building quantitative information into any geoscience course can be challenging (**Manduca et al., 2008**). The authors list specific skills that are important for geoscience students as follows: basic arithmetic, algebra, and statistics; the ability to use equations and models to describe natural processes; estimation and back-of-the-envelope calculations; and modelling and understanding uncertainty.

Macdonald and McNeill Bailey (**2000**) described the departmental context and their approach (known as the matrix approach) to developing skills across the departmental curriculum (**Table 1**). The quantitative components they identified as most important included estimating, measuring, and determining rates of earth processes, modeling earth processes, doing geochronological calculations, and statistically analysing data. Examples included using real data to estimate and measure ground-water-flow velocities, erosion rates, weathering rates, and tectonic plate velocities. They noted how some students had been quite hostile to quantitative work (based on student comments), whereas at the time of writing their paper (2000) such work was simply accepted. Briefly, following the identification of critical quantitative skills and applications (the matrix approach), faculty members in the department systematically incorporated quantitative activities in geoscience courses throughout the curriculum. Of course, faculty members had to be willing to discuss their courses in detail and change course content and activities as necessary.

Quantitative component	Physical Geology, Geography	Historical geology	Mineralogy	Petrology	Sed/Strat	Surficial processes	Paleontology	Structural geology
Estimating	M	L	L	L	M	M	L	M
Measuring	L	M	M	M	M	M	H	H
Determining rates	H	M	L	L	M	H	M	M
Graphing	M	L	M	H	L	M	M	H
Modelling	L	L	M	M	L	H	L	M
Geochronology	M	M	L	L	M	H	L	H
Statistics	L	L	L	M	M	M	H	M

Table 1: Matrix of quantitative components versus core curriculum courses with light (L), medium (M), and heavy (H) reflecting the emphasis of a particular component in a specific course (**Macdonald and McNeill Bailey, 2000**)

Ma (**2019**) points out how Earth science, like other scientific disciplines, is increasingly becoming quantitative because of the digital revolution. At the modern workplace, quantitative analysis is equivalent to numeracy a century ago and literacy before that. The author highlights the importance of the quantification of scientific and technical problems as the core of the ongoing 4th industrial revolution that includes digitalization and artificial intelligence. The author remarks that quantitative analyses of geosciences are not to replace their descriptive counterparts but to complement and enhance them. According to the author, the large potential of big data and quantitative methods is not yet universally recognized in the geoscience community, due, in part, to a lack of familiarity. Essentially, quantitative analysis and modelling are foundations for testing the geological concepts and hypotheses in a quantitative manner. Hereby, probabilistic analytics is used to resolve inconsistency in various data and integrate them coherently. Furthermore, 3D reservoir modelling of heterogeneous subsurface formations has become increasingly important. The essence of modelling lies in using all the relevant data to build an accurate reservoir model that is fit-for-purpose to the business and/or research needs. **Ma** (**2019**) points out that heterogeneities in subsurface formations are complex, and effective application of statistics to subsurface geoscience problems requires immersion in the underlying subject matter. One respective example was elaborated by **Maniar et al.** (**2018**) by using the potential of machine learning to address complex geoscientific problems such as seismic fault interpretation and well log correlation. Their work is based on deep neural networks with modern constructs. These models, together with large datasets, extract relevant features from the data and predict the response variables reliably and precisely with minimal or no human interaction. For example, the authors showed qualitatively how well the model predicts faults on the test crossline sections of seismic datasets.

4. Big data and machine learning in geosciences

Geoscience students should be familiar with concepts such as big data, cloud, and the Internet of Things (IoT). Briefly, computers are searching for trends in enormous collections of information, a task that would be impossible to humans. Within the past 10-15 years, improvements in data processing have made a comprehensive analysis of enormously huge amounts of data possible. In other words, big data is about finding data needles in data haystacks, and each step in a complex manufacturing process can generate tremendous amounts of data (**URL 4**).

Since scientific research has resulted in the accumulation of a large amount of data and conventional methods cannot handle such a massive amount of data, alternatives such as big data, cloud computing, artificial intelligence, and block chain have emerged. Scientific big data is characterized by its non-reproducibility, high degree of uncertainty, high dimensionality, and high complexity. Therefore, big data is a new challenge for conventional data processing techniques and methods (**Qi and Xuelong, 2019**). The authors explain how big data research progresses via the determination of correlations among data and is characterized by decision-making based on high probability. Combined with the advantages of using machine learning algorithms for data processing, methods of data analysis facilitated advancements of the geoscience into new realms of quantitative research. For example, **Ma** (**2019**) gives an excellent remark that data cannot speak for itself unless data analytics is employed. The author emphasizes the importance of in-depth data analytics, as many exotic modelling methods do not generate good reservoir models, because they tend to have too many assumptions, either explicit or implicit, and work well only for synthetic data. To tell a story with geoscience data, numerous hurdles need to be solved. Not only that, but science career stories usually unfold with all their unexpected twists and turns. For example, skills used to be broad, then specialized, and now broad is stellar again. From the book by **Ma** (**2019**), the revolution brought by the geological and reservoir modeling is that it requires a geoscientist who has a broad knowledge in many disciplines (e.g., structural geology, sequence stratigraphy, siliciclastic geology, carbonate geology, sedimentary geology, etc.). Big data have made multidisciplinary skills even more desirable, especially for geosciences applied to resource characterization and modeling. Therefore, integrated modeling using geology, geophysics, petrophysics, reservoir engineering, data science, and geostatistics becomes increasingly important. Prospective geoscience students should learn this along the way and imagine how it may play out for them in their future dream job.

More and more, we read how data is our most valuable asset. According to an article (**URL 5**) in the leading financial magazine (The Economist), the world's most valuable resource is no longer oil, but data. Alphabet (Google's parent company), Amazon, Apple, Facebook and Microsoft, they are the five most valuable listed firms in the world. Without any doubt, we live in the era of the data economy. Economists, professors and even CEOs are touting that data is the new oil in today's economy (**URL 6**). But oil is finite, and it will become harder to extract as less is available. Also, oil is just oil, used in many products. Data, on the other hand, is growing rapidly, it can become any number of things, and data mining has a much less detrimental impact on the environment. Hence, data should be compared with renewables (the sun, water, and wind) since there is an abundance of those. So, the proponents and opponents agree on the one thing, which is the power that comes from the resource, while treating data like oil only contributes to the imbalance of power; those who have the resources and those who don't (**URL 6**).

In 2021, a Thematic Section of Geoscience Frontiers (journal) was devoted to insights into the latest developments and challenges in applying big data and machine learning (ML) to geoscience and geoengineering. Editorial section (**Zhang et al., 2021**) points out that the nature of scientific geoscience and geoengineering data, and the processes used to retrieve and analyse them, may differ substantially from those in other fields. Therefore, geoscience and geoengineering professionals should pay increased attention to big data research, create the environment to utilize data to add value to the geoscience, and promote collaboration with data analysts from other disciplines. The authors explain ML as the scientific study of algorithms and statistical models that allows computers to learn from existing data to improve their performance on specific tasks without being explicitly programmed. Thanks to peculiar features of geological materials, the geoscience and geo-engineering disciplines face more significant uncertainties than other fields of civil and mechanical engineering. Based on considerable monitoring and site investigation data in geotechnical engineering, ML can be a suitable and effective alternative for the purpose of solving various geotechnical engineering problems. In doing so, the combination of big data and ML may create unexpected solutions to the conventional geotechnical problems. Hereby, **Wang et al.** (**2020**) used a large volume of landslide data compiled in Hong Kong over the past few decades and introduced a novel ML and deep learning method to identify natural terrain landslides. Different types of landslide-related data were compiled, including topographic data, geological data and rainfall-related data. Three integrated geodatabases were also established, represented by Recent Landslide Database, Relict Landslide Database and Joint Landslide Database. Promising results were achieved by ML and deep learning methods, particularly the convolutional neural networks (CNN) method, owing to its strengths in feature extraction and multi-layer two-dimensional data processing, which are important for landslide identification problems.

Karpatne et al. (**2017**) discussed some of the emerging research themes in ML that are applicable across all problems in the geosciences, and the importance of a deep collaboration between ML and geosciences for synergistic advancements in both disciplines. They emphasize that the analysis of geoscience data has several unique aspects that are strikingly different from standard data science problems encountered in commercial domains. Noteworthy, geoscience phenomena are governed by physical laws and principles and involve objects and relationships that often have amorphous boundaries and complex latent variables. Furthermore, spatio-temporal structure of geoscience phenomena should be considered, also the facts that they are highly multi-variate, that they follow non-linear relationships (e.g., chaotic), that they show non-stationary characteristics, and commonly involve rare but interesting events. Moreover, the procedures used for collecting geoscience observations (or samples) introduce more challenges for ML, such as the presence of data at multiple resolutions of space and time, with varying degrees of noise, incompleteness, and uncertainties. Additional difficulties refer on the small sample size (e.g., small number of historical years with adequate records) and lack of gold-standard ground truth in geoscience applications. So, the article by **Karpatne et al.** (**2017**) addresses challenges, problems, and promising ML directions, and demonstrates the great emerging possibilities of future ML research in the important geoscience area of research.

Due to a large and complex nature of geological research objects, traditional geological research is often coupled with problems related to complex data sources and low precision. Lately, a huge number of emerging technologies (artificial intelligence, AI) are improving the precision of geological data and expand the data volume. Nevertheless, big data and AI-based geoscience applications are still in their infancy, and the methods and objectives are still scattered, lacking a unified theoretical and application framework (**Chen et al., 2020**). By comparing with traditional geological research methods, big data and AI can take advantage of the vast amounts of geological data to summarize geological characteristics; explore the rules of geological activity; analyse geological phenomena objectively, impartially, and quickly; and provide more scientific results for geological work. The authors give an optimistic message that geological big data technology research will inject new vitality into the development of geology.

Two computer scientists, Thul D. and Blevins K. (**URL 7**) delivered a virtual meeting on new computer approaches (data analysis, machine learning, and big data) to data science in geology (petroleum systems). The authors nicely said that the principal skill of geoscientists is applying domain expertise to sparse data. Something computers, no matter how sophisticated, can't do. In fact, geoscientists recognize patterns and find trends, mostly visually. Hence, the two explored how geologists might leverage new technology to augment their capability and shift cognitive load to computer systems to greatly change information flow and decision making.

Nativi et al. (**2015**) discussed the impact of big data dimensionalities (commonly known as 'V' axes: volume, variety, velocity, veracity, visualization) on the Global Earth Observation System of Systems (GEOSS) and particularly its common digital infrastructure (the GEOSS Common Infrastructure). GEOSS is a global and flexible network of content providers allowing decision makers to access an extraordinary range of data and information. GEOSS is a pioneering framework for global and multidisciplinary data sharing in the EO realm. The authors introduced and discussed the general GEOSS strategies to address big data challenges, focusing on the cloud-based discovery and access solutions.

5. Geoscientists need coding and programming

Once we've established awareness of the quantitative nature of the contemporary geosciences, the next step is to grow the business. Coding makes computers work. Coders are always looking for a way to do something better. Coding is the business literacy of the future. Coding skills are in high demand across a broad range of careers. Coding skills provide an avenue to high-income jobs (**URL 8**). And so on… Essentially, coding is assigning a computer a task to do based on some logic. Highly complex tasks are a collection of smaller operations once they are broken down. This methodical and logic-heavy approach to problem solving can be a boon for figuring out problems beyond a coding challenge (**URL 9**).

Programming skills are commonly perceived as a tool just for modelers or quantitative scientists, but **Valle and Berdanier** (**2012**) dispute this view and argue that programming skills are extremely useful for almost any scientist, particularly with the advent of scripted analysis programs (e.g., Matlab and R). For example, these programming skills enable us to query, pre-process, visualize, and analyse data sets in a much less error-prone way than spreadsheets. Furthermore, these scripting languages allow for a natural documentation of the judgment calls that are often needed when pre-processing the data, being a critical step toward reproducible research. The authors point out that programming skills are critical for data pre-processing, allowing data to be combined, queried, and summarized. These skills are particularly relevant when using data collected by multiple researchers, which is becoming more frequent as we strive to understand environmental (or geological) phenomena across larger regions and over longer time scales. They conclude that these languages (e.g. Python, R, Matlab, etc.) should become part of the formal training of scientists so as to facilitate data sharing, reproducible research, and statistical fluency.

Much of contemporary geoscience evolves around novel analyses of large data sets that require custom tools – computer programs – to minimize the drudgery of manual data handling. **Grapenthin** (**2011**) emphasizes that current curricula do not recognize the gap between user and machine. Therefore, students require specialized courses teaching them the skills they need to make tools that operate on particular data sets and solve their specific problems.

On **URL 10**, a computational scientist shares his insights on the best practices to make scientific software better. He notes that while there are still interesting analytical studies to be made, and important data to be gathered, it is increasingly common that PhD students in geodynamics are expected to work exclusively on data interpretation, computational models, and in particular the accompanying development of geodynamic software packages. For example, one of them is GPlates (**Müller et al., 2018**), a virtual globe software that provides the capability to reconstruct geodata attached to tectonic plates to develop and modify models that describe how the plates and their boundaries have evolved through time. It allows users to deform plates and to visualize surface tectonics in the context of convecting mantle structure and evolution by importing seismic tomography models or outputs from geodynamic models. GPlates applications include tectonics, geodynamics, basin evolution, orogenesis, deep Earth resource exploration, paleobiology, paleoceanography, and paleoclimate. The software is enabling end-users in universities, government organizations, industry, and schools to explore the evolution of planet Earth on their desktop.

6. Conclusions

With the advent of new technologies, such as augmented and virtual reality, or the emergence of web 3.0 and promises of a metaverse, the question arises as to what will happen to the labour market in the near and distant future. This paper suggests that it is imperative to start discussing these topics throughout the education system. More and more universities in the world are implementing transformations of curricula because they are realizing that without greater quantitative knowledge and programming skills, students will not be able to compete in any labour market or business domain. All this is taking place in the context of a green and digital transition in which investments are progressively growing, and such sustainable business should result in climate neutrality and greater competitiveness. This paper shows that the wave of newly expected skills has already swept the labour market, and that all higher geoscience education institutions must learn to swim among all these new trends. In today's dynamic business environment, geoscience students are best equipped if they possess both hard (job duties) and soft (personal qualities) skills, aided by quantitative and computing ones. The crises that humanity is going through are new opportunities in new markets, for the improvement of business and educational processes, restructuring, but above all for greater investment. Ambitious and talented geoscience students need to start preparing for better starting positions in their future careers as early as possible through their educational journey. If we all evolve this part of the business, our prospects of better future are clearly in capable hands.

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Sažetak

Značaj računalnih vještina u visokoobrazovnom sustavu geoznanosti za 21. stoljeće

U svijetu se provode brojna istraživanja o tome kako će izgledati obrazovanje u budućnosti. Svjedoci smo rastućeg broja pokazatelja sporog urušavanja obrazovnog sustava kakvog poznajemo. Izgledno je da se visoko obrazovanje približava velikoj prekretnici nakon koje će ono biti diktirano brzinom i fleksibilnošću prilagodbi globalnim promjenama. Sveprisutna digitalizacija, novi trendovi i održivost bit će ključni koncepti poslovnih modela u budućnosti. Uz poznavanje rada na računalu, novim će generacijama trebati i vještine programiranja. Visokoškolski sustav mora što ozbiljnije i hitnije shvatiti ovaj zadatak. Bez navedenih znanja i vještina budućim će zaposlenicima biti teško konkurirati na tržištu rada i/ili dalje napredovati u karijeri. Ovaj članak bavi se pitanjem budućih smjernica glede visokoobrazovnog sustava geoznanosti s obzirom na ubrzan razvoj tehnologija te eksponencijalan rast skupova podataka. Stoga je potrebno imati na umu da će strojno učenje imati sve više uspjeha na tom polju. Primjena računalnih i matematičkih metoda u geoznanostima, uklopljenih u koncept računalnih geoznanosti, odredit će budućnost geologije i srodnih disciplina.

Ključne riječi: geoznanosti, visoko obrazovanje, vještine, zaposlenje, računalne znanosti

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Author's contributions

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