SOCIAL INNOVATIONS IN GEO-ICT EDUCATION AT TANZANIAN UNIVERSITIES FOR IMPROVED EMPLOYABILITY (GeoICT4e)

N. Käyhkö\textsuperscript{a,c}, M. Mbise\textsuperscript{b}, Z. Ngereja\textsuperscript{d}, M.O. Makame\textsuperscript{d}, E. Mauya\textsuperscript{e}, G. Matto\textsuperscript{f}, E. Timonen-Kallio\textsuperscript{g}, R. Rancken\textsuperscript{h}

\textsuperscript{a} Department of Geography and Geology, University of Turku (UTU), Finland, niina.kayhko@utu.fi
\textsuperscript{b} College of ICT, University of Dar es Salaam (UDSM), Tanzania, Mercy Mbise, mercymbise@gmail.com
\textsuperscript{c} Department of Geospatial Sciences and Technology, Ardhi University (ARU), Tanzania, ngereja@gmail.com
\textsuperscript{d} Department of Social Sciences, State University of Zanzibar (SUZA), Tanzania, maqam04@gmail.com
\textsuperscript{e} Department of Forest Engineering and Wood Science, Sokone University of Agriculture (SUA), Tanzania, ernestmauya@gmail.com
\textsuperscript{f} ICT Department, Moshi Co-Operative University, Tanzania, gmatto2004@yahoo.co.uk
\textsuperscript{g} Faculty of Health and Well-being, Turku University of Applied Sciences, Finland, eeva.timonen-kallio@turkuamk.fi
\textsuperscript{h} Department of Bioeconomy, Novia University of Applied Sciences, Finland, romi.rancken@novia.fi

KEY WORDS: Geospatial technologies, Open Data, Challenge-based learning, Multi-Competence Learning, MOOCs, Social Innovations, Curricula development, Learning Services

ABSTRACT:

Geospatial and ICT technologies are making an impact leap due to globally accessible open data solutions addressing environmental and social challenges, such as rapid urbanization, degradation of marine and land environments, and humanitarian crises. We are witnessing a rapid growth of innovations built on data and tools tackling local societal problems. At best, these can provide better opportunities for sustainable solutions and development. The need for geospatial expertise is growing globally, and the required skills and capabilities of experts are changing. Universities need to think that although the future jobs rely on experts’ geospatial data and technology skills, graduates need to have a strong conceptual and practical understanding of societal problems and capacity to co-develop solutions, which generate wellbeing and inclusive development. New generation university graduates need to master the interface between technologies’ potential and societies’ emerging needs, working in a multi-stakeholder environment and creating innovative and impactful solutions. In this paper, we present a model of institutional cooperation between five Tanzanian and three Finnish universities, aiming to tackle this transformative education challenge in Tanzania. GeoICT4e aims to develop innovative and scalable geospatial and ICT e-learning services for Tanzanian universities. Via this transformation, universities are aiming to enhance the future employment potential of the graduates with digital multi-competence skills. We present the overall methodology and key activities of the project cooperation, and discuss the opportunities and challenges related to this transformation, and use of open data and FOSS solutions particularly from the institutional and societal perspectives.

1. INTRODUCTION

1.1 From technological to social innovations

Geospatial data and ICT technologies have made a major global accessibility and impact leap over the last years, leading to promising technological innovations all over the world. Global data repositories and platforms such as Open Street Map, Google Earth Engine, Earth Explorer, and ESA Sentinel data hub have enabled online and open access to vast amounts of spatial data without major local investments to physical data infrastructures. Geospatial data, technology and application markets are booming and these developments are speeded up with more accessible digital data processing environments, with integrated machine learning and artificial intelligence algorithms, as well as automation and IoT solutions (Madhavan, 2018, Sullivan et al., 2018, GeoBuiz, 2019). As a result, we are currently witnessing rapid growth of digital data collection, mapping and monitoring solutions built on open geospatial data, affordable mobile technologies and earth observation data and methods.

Rapidly developing countries have a vast amount of environmental and social problems, especially when looking at them through the lenses of sustainable development. These real world needs are contextual and dynamic in space and time and call for novel data and technology solutions. We have already seen several examples of how these opportunities can be turned into local solutions that are able to address major planetary challenges, such as rapid urbanization, degradation of marine and land environments and humanitarian crises caused by natural disasters such as earthquakes and floods (Goodchild and Glennon, 2010, Avle et al., 2018, Petersson et al., 2020). Drones (UAVs) have diversified and made mapping and monitoring opportunities cheaper, efficient and accessible (Tiwari and Dixa, 2015). Participatory data collection and citizen science initiatives have transformed the ways digital data and services can be built in previously data-scarce environments for improved sustainability (Bakker and Ritts, 2018, Fritz et al., 2019). These are just a few examples of the prominent directions. Despite these positive developments, there are major concerns if digital innovations built on new technologies and globally accessible data are able to bring inclusive and sustainable development opportunities for the people and the communities locally.

It is important to ensure that the digital divide, which we have witnessed distinctively during the COVID-19 outbreak, is diminished by actions at multiple levels from policy to
institutions, to education and research and workforce actions (Young et al., 2020, UNCTAD, 2021). During the digital era, we should not be content with data and technology advancement only, but thrive for turning these resources into social innovations, which catalyse growth and increase the wellbeing of the people and the planet. At best, sustainable innovations happen in a dynamically evolving interface between technologies’ potential and societies’ emerging needs. Solutions, which are contextually clever, adaptive and driven by local talent and strong linkages to local innovation ecosystem, are much needed. Putting local social, cultural, economic and environmental impacts in the forefront is a service for the sustainable and secure future of the data and technology achievements.

1.2 Need for transformative change in learning and competence development

The opportunity space of social innovations calls for transformation in the ways future geospatial and ICT experts are educated and how their professional skills and competences are built while they are studying and getting prepared for the work life. New generation students and graduates need strong geospatial data and tool competences, but they also need to understand societies’ emerging needs and sustainability challenges in a contextually clever and forward-looking way. Increasingly it is not only how technology savvy students are, but how do we strengthen their intellectual understanding of the complex real-word problems and their capacity and cleverness to cooperate and link with different type of people and knowledge requirements. Thus, students need coaching into proactive and participatory ways of working together with the problem-owners in the society in order to turn universal tools and open data into locally relevant and impactful solutions.

Such learning conditions will not happen in conventional classroom teaching or learner-instructor set-ups, but rather in such environments, where teams of students with different skills work with real world challenges and are able to co-create new ideas and solutions (Martin and Bollinger, 2018, Portugalz Castro and Gómez Zermeño, 2020, Rädberg et al., 2020). If students obtain relevant skills and professional confidence during their studies, they become stronger future problem-owners in the society in order to turn universal tools and open data into locally relevant and impactful solutions.

1.3 Geospatial and ICT learning and skills development needs in Tanzanian universities

In Tanzania, geospatial-ICT education has taken giant steps during the last years in terms of new degree programmes, growth of basic geospatial data and technology skills of staff and students and new infrastructures and tools (Käyhkö et al. 2018a). This has been a result of multiple co-existing initiatives and developments in geospatial and ITC education, research and capacity building activities between Tanzanian universities and their many international partners. Various government, private sector and NGO initiatives and several donor-funded projects have also triggered new needs for new digital geospatial data and technology solutions. These have recently expanded geospatial expertise demand outside traditional geoinformation and surveying domains. As couple of recent examples, Tanzania President's Office-Regional Administration and Local Government is currently implementing a program to mainstream GIS in twenty Local Government Authorities. Integrated Urban Development Project (BIG-Z) on the other hand aims at improving living conditions and promote local economic development in Zanzibar largely with the support of digital geospatial data and technologies (see: http://bigzanzibar.org/).

Despite positive changes, universities’ education has several development challenges amidst these digitalization and growth opportunities. Firstly, teaching focuses still too much on increased enrolment without considering new strategies for delivery of practical skills learning to a large number of students inside and outside universities. Secondly, staff’s skills and capacities have improved but teachers need support to transform their skills to pedagogically high-quality e-learning materials and diverse learning solutions for their students also outside classrooms and in innovative set-ups. Thirdly, students are gradually stronger with basic level geospatial and ICT skills, but they have limited opportunities to widen and apply these skills during their studies and be challenged to create new solutions for new needs in the society. Deeper learning, and adoption of entrepreneurial mind-set does not happen unless students get exposed to learning in multi-disciplinary cross-program setups, solving real-world challenges. Furthermore, multi-domain skills learning requires access to digital geospatial data. Students’ access to reliable digital data, cloud platforms for data processing and e-learning resources in general needs to be improved as part of the universities’ study programmes and courses.

Altogether, lack of applied skills and contextual understanding of the society's needs and sustainability dimensions increases a risk that universities' supply of graduates is unable to respond to increasingly diversifying digital solution demands in the society. This again increases the risk that digital jobs related to geospatial skills are taken by foreign experts, rather than become populated with local talents. Universities alone,
The GeoICT4e project couples tightly with the ongoing World Bank-funded Tanzania Resilience Academy (RA, https://resilienceacademy.ac.tz/), which is coordinated by UTU, UDSM, ARU, SUA and SUZA. Resilience Academy is a World Bank -led university partnership and service delivery program aiming to improve digital skills, competences and employment of the African youth for more effective disaster risk management. Resilience Academy has been operational in Tanzania since 2018 as a cooperation between the World Bank, the universities and the national and international partners of the Tanzania Urban Resilience Programme (TURP).

2.2. Co-creative challenge campaigns and multi-competence learning

The central vehicle for education transformation in GeoICT4e is the students’ multicompetence learning (MCL) process, which happens via co-creative challenge campaigns organized in close cooperation with the innovation ecosystem actors and problem owners. This methodology enables universities to catalyse a change, which we identify as ‘socially innovative geospatial and ICT education transformation’ (Figure 1). The essential elements of the MCL approach, which is grounded on the principles of challenge-based learning (Rädberg et al., 2020), is that students’ competences improve simultaneously in multiple knowledge domains.

Figure 1. GeoICT4e is aiming for socially innovative geospatial and ICT education transformation, which endorses multi-competence learning (MCL) opportunities of the students.
Firstly, students are solving real, complex problems of the surrounding society and thus they need to understand the root causes and consequences of the problems and their spatial and temporal dimensions. Secondly, students need to obtain skills in collecting and using digital geospatial data and open-source geospatial and ICT technologies in a novel manner. Digital data is a key asset for problem solutions and mastery of the data and tools with local users is a crucial asset for inclusive design of the solutions. Thirdly, students’ abilities and professional confidence evolve in multi-stakeholder teams so that they know how to approach real-word challenges in a contextually clever manner, working for problem-owners towards innovative and influential solutions. Fourthly, global change is creating uncertainty and unpredictability to our socio-ecological systems. Students need to have skills to design climate-smart and resource-efficient solutions for social, cultural, environmental and economic sustainability and improved resilience.

The MCL process leans on challenge based learning (CBL) principles (Blevis, 2010, Gaskins et al., 2015, Malmqvist et al., 2015, Rådberg et al., 2020), where learning is organized around real-life challenges provided by external partners and carried out in student- and teacher-led multi-disciplinary teams. Students will formulate a concrete actionable challenge based on a broader societal challenge, investigate, research, brainstorm solution concepts and strategies, implement solution prototypes and evaluate them together with real stakeholders in order to provide a pragmatic, progressive learning experience in boosting students’ professional development and competences. The essential idea in GeoICT4e is that we link CBL learning to the above-mentioned multicompetence learning themes. The MCL learning takes place through 3-5 months long co-creative challenge campaigns, where students’ skills and professional competencies develop in relation to the challenge at hand. The team will organize five challenge campaigns during the course of the project, each led by a local university, and supported by a team of experts from all universities and innovation partners (Figure 2). CBL pedagogy means changing the role of university teachers. They are urged to reflect and co-create (Figure 2). CBL pedagogy means changing the role of university teachers. They are urged to reflect and co-create on the university teachers. They are urged to reflect and co-create. This means they know how to approach real-world challenges in a contextually clever manner, working for problem-owners towards innovative and influential solutions. Fourthly, global change is creating uncertainty and unpredictability to our socio-ecological systems. Students need to have skills to design climate-smart and resource-efficient solutions for social, cultural, environmental and economic sustainability and improved resilience.

The MCL process leans on challenge based learning (CBL) principles (Blevis, 2010, Gaskins et al., 2015, Malmqvist et al., 2015, Rådberg et al., 2020), where learning is organized around real-life challenges provided by external partners and carried out in student- and teacher-led multi-disciplinary teams. Students will formulate a concrete actionable challenge based on a broader societal challenge, investigate, research, brainstorm solution concepts and strategies, implement solution prototypes and evaluate them together with real stakeholders in order to provide a pragmatic, progressive learning experience in boosting students’ professional development and competences. The essential idea in GeoICT4e is that we link CBL learning to the above-mentioned multicompetence learning themes. The MCL learning takes place through 3-5 months long co-creative challenge campaigns, where students’ skills and professional competencies develop in relation to the challenge at hand. The team will organize five challenge campaigns during the course of the project, each led by a local university, and supported by a team of experts from all universities and innovation partners (Figure 2). CBL pedagogy means changing the role of university teachers. They are urged to reflect and co-create (Figure 2). CBL pedagogy means changing the role of university teachers. They are urged to reflect and co-create. This means they know how to approach real-world challenges in a contextually clever manner, working for problem-owners towards innovative and influential solutions. Fourthly, global change is creating uncertainty and unpredictability to our socio-ecological systems. Students need to have skills to design climate-smart and resource-efficient solutions for social, cultural, environmental and economic sustainability and improved resilience.

2.3 Development of open-access e-learning assets

Our education transformation will accelerate multiple learning opportunities within and outside universities when we make all our learning assets digital and open, and widely accessible for anyone to use. This concerns digital geospatial data, which we will store, share and reuse, and e-learning materials, which we package into nugget-sized mini-MOOCs and self-study packages and serve them free-of-charge for self-studying. The project team aims to publish 40-50 open-access learning material packages during the project. The topics of these e-learning materials cover the four key domains of our MCL model. We make these e-learning packages rather compact in size (mini-MOOCs) and endorse the following qualities. Firstly, each learning package takes only one to two days to study. Secondly, each package consists of a combination of small learning entities (nuggets), such as mini-lectures served as videos, quizzes and practical tasks. Thirdly, materials are designed so that they facilitate primarily independent learning, and the packages and their nuggets can thus be flexibly integrated into any local course and context. Finally, materials will be openly available e-learning resources shared via DigiCampus platform (https://digicampus.fi/?lang=en).

We will also utilize globally available open learning materials and MOOCs in combination with these locally made materials. The team will also promote usage of global and regional open-access geospatial data repositories and platforms to ensure that practical nuggets use real geospatial data sets relevant for the course topic. We aim to gather Tanzania-specific geospatial data sets to an open-access data repository using Geonode to facilitate education and research related learning opportunities of the students with local data sets. These actions will expand our already established digital geospatial data services of the Tanzania Resilience Academy (Climate Risk Database, https://geonode.resilienceacademy.ac.tz/). On top of these consortium wide efforts, the project also supports local investments at the universities for e-learning environments. These investments are made at each university based on their local needs.

2.4 Integrating solutions to local curricula and courses

Nearly 50 senior and junior level experts from the partner universities implement the project. On top of coordination and management work, experts work in small thematic teams co-designing the activities and ensuring the institutional uptake of
the e-assets and CBL-MCL pedagogy innovations (Figure 3). The core team related to the institutional uptake are the experts in charge of the CBL-MCL learning methodology development, e-assets and mini-MOOCs and curricula and course developments. For each CBL campaign, there will be multiple innovation and society experts, who are able to provide insights into the challenges from the perspective of the problems’ spatial and temporal dimensions and local context, as well as entrepreneurial approach and innovation aspects. Experts also work closely in university-specific teams to develop their localized learning service solutions based on collectively produced e-assets. Teams continue an already earlier initiated development of undergraduate and postgraduate programs and courses towards improved contents and pedagogy (Käyhkö et al. 2018a, Leinonen et al. 2018).

Institutional confidence, co-learning and sharing of good practices is grounded on individual experts knowing each other and being motivated to share their experiences related to institutional opportunities and challenges and piloting new solutions. Furthermore, awareness and marketing of the work to a higher level at each university is an important aspect of the cooperation and institutional acceptance of the work of the team. Thus, GeoICT4e funding is facilitating staff mobility within Tanzania and between Finland and Tanzania, training of the trainers -sessions physically and online, organising cooperation and co-design workshops and participation in education, science, technology and innovation events to share experiences. As institutional competence development is a long-term, evolutionary process, the project is putting specific emphasis on improving management capacities related to the cooperation space contains many assumptions and risks, which may slower anticipated results. One of the key assumptions is related to the overall digitalization and innovation sector development in Africa and in Tanzania in particular. We assume that the trend is positive and that both policy environment as well as investments will flow to Tanzania regarding various industry sectors typically relying on digital data and location technologies. Location-technology, geospatial data, Earth Observation, ICT and AI solutions are also likely to spread from their traditional application sectors to wider location-intelligence business solutions, as we see globally happening. Geospatial solutions have finally become ubiquitous and integrated into most of the ICT sector system and service solutions (GeoBuiz, 2019). It is vital that when these technologies are turned into local services, locally competent workforce is available and is used. There is also an anticipation that the digital job market creates a strong niche for open data and open-source technology solutions, endorsed by local and international institutions and investors (Johnson et al., 2017, Käyhkö et al., 2018b), Innovation ecosystem and close interaction and cooperation between different knowledge domains are important enablers in the creation of collaborative atmosphere, where open data and tools turn into locally valuable assets and solutions. Governments’ and universities’ skills development and employment strategies, STI policies and teaching practices are crucial elements supporting education transformation to innovative, directions meeting various societal needs. In case these assumptions are realized and risks minimized, universities skilled geospatial and ICT graduates, who have witnessed several successful problem-solving learning cases in

| 3. CONCLUSIONS |

Institutional development projects’ true impacts are discovered usually over a long-time period. The objectives of the GeoICT4e project are ambitious and aim for transformative change, which happens between the universities’ learning services and societies’ needs for skilled workforce and commitments to enhance life qualities with innovative means. Success of this transformation is dependent on many interlinked issues, which are not restricted only to actors and institutions, experts, students and their capacities. Instead, there are many societal factors, which challenge success of innovative education initiatives. By working in close cooperation with innovation ecosystem actors and processes, universities will improve their success potential in making geospatial and ICT education more relevant and influential but this cooperation space contains many assumptions and risks, which may slower anticipated results. One of the key assumptions is related to the overall digitalization and innovation sector development in Africa and in Tanzania in particular. We assume that the trend is positive and that both policy environment as well as investments will flow to Tanzania regarding various industry sectors typically relying on digital data and location technologies. Location-technology, geospatial data, Earth Observation, ICT and AI solutions are also likely to spread from their traditional application sectors to wider location-intelligence business solutions, as we see globally happening. Geospatial solutions have finally become ubiquitous and integrated into most of the ICT sector system and service solutions (GeoBuiz, 2019). It is vital that when these technologies are turned into local services, locally competent workforce is available and is used. There is also an anticipation that the digital job market creates a strong niche for open data and open-source technology solutions, endorsed by local and international institutions and investors (Johnson et al., 2017, Käyhkö et al., 2018b), Innovation ecosystem and close interaction and cooperation between different knowledge domains are important enablers in the creation of collaborative atmosphere, where open data and tools turn into locally valuable assets and solutions. Governments’ and universities’ skills development and employment strategies, STI policies and teaching practices are crucial elements supporting education transformation to innovative, directions meeting various societal needs. In case these assumptions are realized and risks minimized, universities skilled geospatial and ICT graduates, who have witnessed several successful problem-solving learning cases in
Tanzania, will hopefully be well positioned in the society to catalyse the growth further and open new opportunities for the students, who follow their steps in the future.

ACKNOWLEDGEMENTS

We are grateful for the financial support for the project from the Ministry for Foreign Affairs of Finland via the HEI-ICI programme. The Higher Education Institutions Institutional Cooperation Instrument (HEI-ICI) supports cooperation projects between higher education institutions in Finland and the developing world. The projects support the HEIs as they develop their subject-specific, methodological, educational and administrative capacity. The programme is funded by the Ministry for Foreign Affairs of Finland and administered by the Finnish National Agency for Education. We would like to thank our home institutions of their financial and collegial support, and all the GeoICT4e and Resilience Academy team members and innovation ecosystem partners for their enthusiasm and cooperation in the project.

REFERENCES

Avle, S., Quartey, E., Hutchful, D. 2018: Research on Mobile Phone Data in the Global South: Opportunities and Challenges. The Oxford Handbook of Networked Communication. 84. doi.org/10.1093/oxfordhb/9780190460518.013.33.

Bakker, K., Ritts, M. 2018: Smart Earth: A meta-review and implications for environmental governance. Global Environmental Change 52, 201–211. doi.org/10.1016/j.gloenvcha.2018.07.011.

Blevis, E. 2010: Design Challenge Based Learning (DCBL) and Sustainable Pedagogical Practice. Interactions 17, 64-69. doi.org/10.1145/1744161.1744176.

Fritz, S., See, L., Carlson, T., Haklay, M., Oliver, J.L., Dilek F., Mondardini, R., Brocklehurst, M., Shanley, L.A., Schade, S., Wehn, U., Abrate, T., Ansect, J., Arnold, S., Billot, M., Campbell, J., Espey, J., Gold, M., Hager, G., He, S., Hepburn, L., Hsu, A., Long, D., Masó, J., McCallum, I., Muniafu, M., Moorthy, I., Obersteiner, M., Parker, A.J., Weisspflug, M., West S. 2019: Citizen science and the United Nations Sustainable Development Goals. Nature Sustainability 2, 922–930. doi.org/10.1038/s41893-019-0390-3.

Gaskins, W.B., Johnson, J., Maltbie, C., Kukreji, A. 2015: Changing the Learning Environment in the College of Engineering and Applied Science Using Challenge Based Learning. International Journal of Engineering Pedagogy 5(1). http://dx.doi.org/10.3991/ijep.v5i1.4138.

GeoBuiz 2019: Geospatial Industry Outlook & Readiness Index. https://issuu.com/geospatialworld/docs/20190329-geobuiz-report-2019-freeve.

Goodchild, M., Glennon. A. 2010: Crowdsourcing geographic information for disaster response: a research frontier. International Journal of Digital Earth 3, 231-241.

Johnson, P.A., Sieber, R., Scassa, T., Stephens, M., Robinson, P. 2017: The Cost(s) of Geospatial Open Data. Transactions in GIS 21, 434–445. doi.org/10.1111/tgis.12283.

Käyhkö, N., William, C., Mayunga, J., Makame, M., Mauya, E., Järvi, A. 2018a: Building geospatial competences in Tanzanian universities with open source solutions. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, XLII-4/W8, doi.org/10.5194/isprs-archives-XLII-4-W8-93-2018.

Käyhkö, N., Makandi, H., Msilanga, M. 2018b: Geospatial expertise, cooperation networks and development potential in Tanzania. https://agile-online.org/conference_paper/cds/agile_2018/shortpapers/153%20AGILE_2018_NKayhko_revised_April10th.pdf.

Leinonen, U., Koskinen, J., Makandi, H., Mauya, E., Käyhkö, N. 2018: Open Foris and Google Earth Engine linking expert participation with natural resource mapping and remote sensing training in Tanzania. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, XLII-4/W8, doi.org/10.5194/isprs-archives-XLII-4-W8-117-2018, 2018.

Madhavan, R. 2018: Robotics and automation for societal good. Global South challenges and technology-policy considerations. Métode Science Studies Journal 2018, 153-161. doi.org/10.7203/metode.9.12222.

Malmqvist, J., Kohn Rådberg, K., Lundqvist, U. 2015: Comparative Analysis of Challenge-based Learning Experiences. Chengdu University of Information Technology, 11th International CDIO Conference, China. June 8-11, 2015.

Martin, F., Bolliger, D.U. 2018: Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. Online Learning, 22, 205-222. dx.doi.org/10.24059/olj.v22i1.1092.

O’Sullivan, C., Wise, N., Mathieu, P.P. 2018: The Changing Landscape of Geospatial Information Markets. In: Mathieu, P.P., Aubrecht, C. (eds), Earth Observation Open Science and Innovation. ISSI Scientific Report Series, vol 15. Springer, Cham. doi.org/10.1007/978-3-319-65633-5_1.

Pettersson, L., ten Veldhuis, M.-C., Verhoeven, G., Kapelan, Z., Maholi, I., Winsemius, H. 2020: Community Mapping Supports Comprehensive Urban Flood Modeling for Flood Risk Management in a Data-Scarce Environment. Frontiers in Earth Science 8, 304. doi.org/10.3389/feart.2020.00304.

Portugal Castro, M., Gómez Zermeño, M.G. 2020: Challenge Based Learning: Innovative Pedagogy for Sustainability through e-Learning in Higher Education. Sustainability 12, 4063. doi.org/10.3390/su12104063.

Rådberg, K.K., Lundqvist, U., Malmqvist, J., Svensson, M. 2018: From CDIO to challenge-based learning experiences – expanding student learning as well as societal impact? European Journal of Engineering Education 45, 22-37. doi.org/10.1080/03043797.2018.1441265.
Tiwari, A., Dixit, A. 2015: Unmanned Aerial Vehicle and Geospatial Technology Pushing the Limits of Development. American Journal of Engineering Research (AJER) 4, 16-21.

UNCTAD (United Nations Conference on Trade and Development), 2021: Technology and Innovation Report 2021. Catching technological waves: Innovation with equity. https://unctad.org/system/files/official-document/tir2020_en.pdf (Accessed on June 15th, 2021).

Young, J.C., Lynch, R., Boakye-Achampong, S., Jowaisas, C., Sam, J., Norlander, B. 2020: Volunteer geographic information in the Global South: barriers to local implementation of mapping projects across Africa. Geojournal doi.org/10.1007/s10708-020-10184-6.