International Journal of Sustainable Development & World Ecology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsdw20

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To cite this article: Walter Leal Filho, Amanda Lange Salvia, Ali Beynaghi, Barbara Fritzen, Azeiteiro Ulisses, Lucas Veiga Avila, Kalterina Shulla, Claudio R. P. Vasconcelos, Sara Moggi, Mark Mifsud, Rosley Anholon, Izabela Simon Rampasso, Valerija Kozlova, Dzintra Iliško, Antonis Skouloudis & Ioannis Nikolaou (2024) Digital transformation and sustainable development in higher education in a post-pandemic world, International Journal of Sustainable Development & World Ecology, 31:1, 108-123, DOI: 10.1080/13504509.2023.2237933

To link to this article: https://doi.org/10.1080/13504509.2023.2237933

INTERNATIONAL JOURNAL OF SUSTAINABLE DEVELOPMENT & WORLD ECOLOGY
2024, VOL. 31, NO. 1, 108–123
https://doi.org/10.1080/13504509.2023.2237933

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Digital transformation and sustainable development in higher education in a post-pandemic world

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ABSTRACT

Digital technologies are now part of our daily lives, and the speed of their implementation and use has been accelerated as a result of the COVID-19 pandemic. Digital transformation, seen in the past as a problem, is now perceived as an important component in the future of sustainable development (SD), especially at higher education institutions whose operations have been adversely affected by the pandemic in many ways. The purpose of this paper is to analyse the subject matter of digital transformation and how it relates to a SD context. It reports on the results of a worldwide survey at higher education institutions, which identified some areas where the pandemic impacted and/or influenced their activities. The survey received 158 responses and a principal component analysis was performed to model the items associated with digital tools boosting SD, innovative business opportunities and ideas, and needs for improvement at HEIs. The results indicate that most part of the respondents developed digital skills and increased their involvement with e-learning and distance learning; however, more digital training is needed. Findings also support the role played by digital technologies in boosting SD at HEIs, and the role of institutions in promoting innovation through digital tools. Apart from an analysis of the extent to which the COVID-19 pandemic has contributed to digital transformation in an SD context in higher education institutions, the paper provides an assessment of trends and recommendations that may guide future developments in a post-pandemic work.

ARTICLE HISTORY
Received 28 February 2023
Accepted 14 July 2023

KEYWORDS
Sustainable development; sustainable development goals; digital transformation; higher education; COVID-19 pandemic

1. Introducing digital transformation

Digital transformation can be described as changes taking place in society and industries via the use of various digital technologies, infrastructure, and platforms (Majchrzak et al. 2016; Vial 2019). It aims to improve society and business through the use of information, computing, connectivity, and communication technologies that are digitally based (Vial 2019). Even during the pre-pandemic period, the ever-growing technology market, the speed of technological developments, and competition between companies and globalisation have forced companies to go digital, to remain relevant (Reis et al. 2018). Therefore, this concept usually entails organisations (especially companies) developing innovative strategies using digital technologies to allow for more efficient and feasible operational mechanisms (Hess et al. 2016; Vial 2019).

Greater than ever, digital technologies are now part of our daily lives, and the speed of their implementation and use have been accelerated as a result of the COVID-19 pandemic's lockdowns and needs for physical distancing. Aside from the rapid business changes, almost all learning institutions were forced to shift their leaning onto online platforms (Iivari et al. 2020). In some developing countries, this was not always possible, thus highlighting the digital divide that is commonly overlooked. However, learning institutions have now understood the need for digital transformation and are preparing themselves accordingly (Ramij Md and Sultana 2020).

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Educational community needs to develop new abilities 'that could be used to diversify teaching methods to help educators and learners to orientate themselves in the modern learning process' (Trinkūnienė and Juskaite 2021).

Digital technologies are conceived as a complex and interconnected environment that is known to enhance digital learning (Abad-Segura et al. 2020). This revolution in higher education (HE) is driven by the rapid digital transformation where technology has supported online deliveries by tools and platforms for a) learning, teaching, and assessment, b) connecting students, professors, and universities staff, and c) supporting the sharing of resources and contents (Adedoyin and Soykan 2020; Association for Learning Technology 2020; Foundation Education Endowment 2020).

Research has shown that digital transformation has significant implications for the traditional methods used. In order to effectively engage in digital transformation, organisations (business, schools, higher education institutions, among others) require digital resources (Verhoef et al. 2021) such as a) digital assets (infrastructure and storage of data), b) digital agility in order to predict markets and seize opportunities (Lee et al. 2015), and c) skills of the stakeholders' (workers, learners, teachers, and academic staff) to effectively work/study remotely (Fletcher and Griffiths 2020). The usual diffusion of technology and innovation is due to the inevitable development of the educational ecosystem and the shift in service delivery and communication networks (Trinkūnienė and Juskaite 2021).

Additionally, digitalisation causes concern with regards to the privacy and security of users and organizations' data (Nambisan et al. 2019). This caused organizations to identify many gaps in their digitals systems as most were unable to operate online at the beginning of the COVID-19 pandemic. Therefore, they were forced to rapidly put measures into place (Fletcher and Griffiths 2020).

Digital literacy appeared to be a major impediment to digital adaptation in HEIs during COVID-19 pandemic. All the stakeholders face a significant challenge in terms of digital literacy, which necessitates them updating their skills in the field on a global scale (Jakoet-Salie and Ramalobe 2023).

Specially in the education field, preliminary studies have put the attention on digitalisation due to the COVID-19 pandemic in K-12 and high schools underlining some barriers that can hamper this process (Arlinwibowo et al. 2020; Bond 2020). At this level of education, negative impacts are mainly on students' interaction, the effectiveness of distance learning, and inequalities due to the digital dived (Lai and Widmar 2020). Contrariwise, in higher education institutions distance learning was quite widely accepted and seen in its potential also in reducing physical distancing (Bond 2020; Bozkurt 2020; Daniel 2020). Digital pedagogical transformation can not only transform, but also increase the efficiency of teaching and learning processes in achieving all pedagogical development goals (Szűts et al. 2023). In this vein, digitalisation is foreshadowed to be one of the most promising transformations towards SD (Gouvea et al. 2018; Walker et al. 2019; Del Río Castro et al. 2021) in particular in HE (Ahel et al. 2020).For the environment the greatest opportunities of digitization arise in the area of energy; the greatest risks arise in the consumption of resources and the disposal of digital devices (Estermann et al. 2020, p. 4).

HEIs also represent a crucial stakeholder in the promotion and implementation of the United Nations (UN) 2030 Agenda for sustainable development (Vallez et al. 2022) and the digitalisation of society by producing knowledge for new technologies and social innovation (Carayannis and Morawska-Jancelewicz 2022).

Students are expected to develop a holistic understanding of their reality and its main conflicts considering social, environmental, and economic facets (Del Olmo and Sánchez 2019). Digital learning can be an effective ESD tool, in other words, a mean for sharing sustainability experiments and experiences and solving challenges in collaborative ways (Castro and Zermeño 2020). Changes in higher education become necessary and unavoidable along with the changes in the organisation of a learning process and governance by adopting new forms of online professional collaboration, and motivation of students to engage in more student-centred learning.

Digital learning and the use of similar technologies permit to study flexibly and prepares students to work in interdisciplinary environments, orienting students to potential job requirements (Ahel et al. 2020; Gapsalamov et al. 2020). Despite these potentials, the majority of the available studies on digitalisation for SD focus on companies rather little attention has been paid to the impact this transformation can have on HE institutions. Leal Filho et al. (2021) state the current situation triggered by the pandemic 'may serve the purpose of showing how university teaching on sustainability may be improved in the future, taking more advantage of modern information technologies'. In filling this gap, the present study investigates the issue of digital transformation toward SD in HE and its accelerated implementation due to the COVID-19 pandemic. For exploring this issue, a worldwide survey was disseminated to lots of HE institutions.

Through its results, this research contributes to the scant available literature on the emergency digital transformation in HE due to the COVID-19 pandemic and its implementation towards SD. Since the return to normality had not been just a simple step-back transition (Daniel 2020), the paper expected trends and recommendations that may guide future enhancements of HE

in a post-pandemic era, where changes in teaching and learning practices are already taking place. The purpose of this paper is to analyse the subject matter of digital transformation and how it relates to a SD context.

2. Digital transformation and education for SD

The catchphrase of SD has a pervasiveness and massive popularity (Mensah and Ricart Casadevall 2019). Notwithstanding this buzzword's trendiness, the concept of SD emerged some decades ago in the 'Our Common Future Report' (Brundtland Commision 1987), meaning the 'development that meets the needs of the current generation without compromising the ability of future generations to meets their own needs' (Mensah and Ricart Casadevall 2019). Hák et al. (2016) and Kolk (2016) reinforce the triple bottom line of SD, which means the integration of economic growth, environmental integrity, and social well-being in decision-making processes.

'Education is the key to sustainable development' (Burbules et al. 2020) and Sustainable Development Goal 4 focuses on HEIs' task to ensure inclusive and equitable quality education for all and to promote ESD (United Nations 2015). However, higher education institutions face several sustainability challenges: meeting the needs of all, providing the access to resources for all, ensuring fairness, and inclusion to make educational practice more sustainable (UNDP 2011).

Digitalisation has been imposed in all spheres of life to increase SD (Unwin 2009), and it can provide benefits to societies (World Economic Forum, 2021).Hilty and Aebischer (2015) reflect on the need of unleashing the true potential of digitalisation in creating a more sustainable society. Reinforcing sustainability employing digital transformation should encourage sustainable patterns of online interaction and teaching (Goswami 2014).

Digitalisation has some advantages in respect of enhanced data collection, a prompt availability of materials, and flexible use of them across time and geographical scales.

It also has some negative effects such as a higher consumption of energy, a greater reliance on electronic equipment and potential disturbances in social contacts due too much use of virtual meetings.

Besides the health field regarding, for instance, the telemedicine for patients, Burbules et al. (2020) argue new technologies can change ideas, conceptions, and aims also in the education sphere. Digital transformation has provided alternatives to face-to-face learning (Azeiteiro et al. 2015). E-learning can be a mechanism that has a great extent to improve access to education, mainly for higher education students who are simultaneously full-time employees (Azeiteiro et al. 2015), a reality in developing countries. As well as, it has the potential to accomplish sustainable development goals and lifelong learning in ESD (Azeiteiro et al. 2015; Castro and Zermeño 2020).

Nevertheless, digital transformation also brought alongside unsustainable aspects in teaching. They increased social exclusion, digital divide, fostered social inequalities between different groups of students with diverse social incomes and access to higher education. The unavailability of digital resources also caused economic disparity (Michalsen et al. 2020).

Being under the lockdown, in the situation of a 'new normal', higher education was able to respond to the digitalisation challenges both, in sustainable and unsustainable ways. Leal Filho et al. (2021) point out there are many challenges and measures for HEIs, in the future, 'to take more advantage of technologies that support research on sustainable development'.

Henry (2012) states digitalisation and information and communications technologies (ICT) have the potential to become the driving force for SD, which brings more benefits than negative consequences. At the same time, technologies alone do not make a difference, people need to be involved (Loveless et al. 2001). Technologies cannot be the ultimate solution to all problems. But it can be a tool to be used skilfully and professionally by the educator. It has become evident that universities need to become more flexible and sustainable in their policy and practice in facing emerging crises and pandemics by encouraging innovative solutions, ensuring greater flexibility, and adapting resilience (Azeiteiro et al. 2015). Sustainable solutions require time, and they are rewarding in the long run. Burbules et al. (2020) argue these technologies trends carry risks and downsides. All these factors should be carefully evaluated.

3. Impacts of the COVID-19 pandemic on digital services

Many sectors of the society, in order to function during the pandemic crisis created by the COVID-19 pandemic, required a higher level of technological use (Berchin and de Andrade 2020). Education institutions as the most affected, needed to adapt quickly to the new circumstances and to upgrade their technological services. Due to the lockdown and travel restrictions imposed in most of the countries, a wide range of educational activities have switched to online services. Although distance learning and its reliability has grown in the recent years (Sobrosa Neto et al. 2020), i.e. global ed-tech investments before pandemic were about US$18.66 billion in 2019 (Li and Lalani 2020), the scale of technological use during 2020 for educational activities surpassed any potential forecast.

Travel restrictions interrupted many education projects designed for traveling and exchange of students

and academics. Interruption of research may harm especially the young scientists (de Amorim and de Andrade Guerra 2020). Although online conferences are easier to organize than traditional ones and can reach a wider audience, they don't allow for young research visibility for example through poster presentations and informal meetings (Saliba 2020). In order to continue research activities, (use of virtual lab meetings, research seminars, conferences, events) researcher would need more technological resources and capacity development for using them (Leal Filho et al. 2021). But online learning depends heavily on technical infrastructure and digital access but only around 60% of the globe's population is online.

Despite the advantages, there are risks associated with digitization. For instance, the over-use of technology and virtual education may allow a fast spread of false information. An excessive use of digital means may also be associated with mental and physical health problems. In addition, the lack of digital skills and competences, or the lack of proper conditions for work on a home office environment, can cause anxiety and stress, emotional irritation, encourage domestic conflicts and probably result in lower performance and efficacy.

The emergency measures taken by universities and students during the pandemic were in most of the cases successful. But high education communities should now concentrate on long-term planning (IAU & ESN 2020) because traditional education may not return to the conditions before COVID-19. Although the pandemic has highlighted some limitations of higher education systems, there are various means that can assist in the success of technological adaptation in HEIs (Habib et al. 2021). These institutions can drive digital transformation and digital innovation by providing new skills, deploying teaching methods and practicing open science policies (OECD/European Union 2019).

4. Methods

For the purposes of this paper, digital transformation is defined the use of new technologies to stay competitive in the Internet age, where services and products are delivered both online and offline (Mergel et al. 2019). The research gaps this papers address are twofold. Firstly, it addresses the connections between digitization and SD at HEIs. Secondly, it identifies the elements which influence digitization on SD and lists some of the barriers associated with this process. To do so, it uses an exploratory approach to describe the subject matter of digital transformation and relate it to an SD context. Methodologically, a worldwide survey was undertaken at higher education institutions, to identify areas where the pandemic impacted and/or influenced their activities.

The full questionnaire was designed to collect general information and ensure that details were anonymous. In line with procedures in Germany, the survey was not subject to ethical approval. Participants were fully informed about the confidentiality of the study and provided an informed consent for participation in the survey.

A questionnaire with 14 questions has been developed by the research team. The demographic section was composed of 5 questions for sample description (country, gender, age, educational level and position at the university), followed by 9 questions on technical aspects of digital transformation:

(1) Deployment of digital transformation in a sustainable development context: one question was dedicated to assess the extent to which digital transformation could be deployed in a context focused on sustainable development, with options based on Likert Scale (Not at all, Little Extent, Some Extent, Great Extent, Very Great Extent);
(2) Contribution of digital transformation to a series of sustainable development related aspects: respondents should indicate their level of agreement (Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree) on aspects associated with strengthened governance practices and policy coherence at HEIs, delivery of economic and environment benefits from digitally-based technologies at HEIs, strengthened environmental sustainability and reduced vulnerability to pandemics, mitigation of inequalities, limitations in digital connectivity affecting people disproportionally, facilitation of teaching and research on the SDGs, acceleration of progress towards the implementation of the SDGs, improved dimension of teleworking, remote learning and virtual living, and contribution to resilient and sustainable recovery of the COVID-19 pandemic.
(3) Areas that achieved greatest digital transformation by the pandemic: with options for selection including teaching, research, fundraising, event programming, outreach, and administrative sector;
(4) Development of innovative ideas and business opportunities: the extent to which ideas and business opportunities around sustainability could be developed using digital means, with options based on a Likert Scale (Not at all, Little Extent, Some Extent, Great Extent, Very Great Extent);
(5) Development of competences: the extent to which new digital competences in response to the COVID-19 pandemic could be developed (Not at all, Little Extent, Some Extent, Great Extent, Very Great Extent);

(6) Training opportunities: the survey also assessed if universities offered training opportunities to assist in getting those new digital competences, and if this was not the case, if respondents paid for their own training or taught themselves;
(7) Future potential: respondents were asked to select areas in which they see future potential in terms of use of digital technologies – options included: sustainability research, sustainability teaching, in works with external stakeholders, sustainability-oriented innovation, sustainability-oriented projects, and a open space to indicate others;
(8) Challenges: finally, respondents were also asked to indicate the main challenges for the digital transformation accelerated by the COVID-19 pandemic – options included: learning how to use (new) digital tools, avoiding projects' disruptions with colleagues/stakeholders, time management skills in lockdown/home office situations, continuing the development of academic networking/conferences, providing further funding for PD & equipment, protection from technostress and related health issues, and a open space for indicating others.

The questionnaire was pre-tested (Hair et al. 2011) with a group of sustainability researchers to check for clarity and comprehensiveness. This made sure they understood what was asked from them.

For data collection, the online survey disseminated via Google Forms used a snowball sampling approach. The snowball sampling is a nonprobability sampling technique, in the context of which study subjects recruit additional subjects from among their acquaintances (Noy 2008a). It has been deployed in various studies before by the authors, such as on a work focusing on the impacts of the COVID-19 pandemic on SD research Leal Filho et al. (2021) and survey on sustainability practices at HEIs in Latin America Leal Filho et al. (2021). It started with the IUSDRP[1] and co-authors' networks. The data were analysed using the software SPSS to perform descriptive and inferential statistics.

Specifically to shed some light on how digital technologies influence SD initiatives relates to HEIs, business model opportunity and innovative ideas, a principal component analysis (PCA) was performed to model a set of items around a structure that comprises the following four components: (1) digital technology boosting sustainable development at HEIs; (2) digital tools boosting innovative business opportunity; (3) digital tools boosting innovative ideas; and, (4) need to improve digital technologies at HEIs.

The PCA could be defined as a statistical approach employed to analyse the interrelationship among a large number of variables and explain them based on their common latent dimensions (components) (Field 2018; Malhotra et al. 2018). This approach is applied at the aim of find a manner to condensing the information comprised in a number of original variables into a reduced set of dimensions with a minimal loss of information. To test the adequacy of the modelling process the following statistics are recommended in literature: Measure of sampling adequacy (MSA), to evaluate the appropriateness of applying PCA analysis, values greater than .5 meet the threshold; and statistically significant Bartlett's test of sphericity (sig. < .05), which indicates the existence of sufficient correlations among the variances; and finally the Cronbach's Alpha to analyse the reliability of the designed subscales; values higher than .7 are expected (Hair et al. 2014).

5. Results

5.1. Characterization of the sample

A total of 158 questionnaires were collected from 39 countries around the world from the 2nd of February 2021 to 1st of March 2021. Therefore, our survey represents a broad sample of professional practice and options from the global university sector. Respondents were well distributed from around the world, but most replies were received from Europe and America. Most respondents came from Brazil (17%, $n = 27$), Latvia (12%, $n = 19$), the United Kingdom (8%, $n = 13$), and Germany (8%, $n = 13$). When grouped according to continental landmasses, the most represented region was Europe with 54.4% of the replies, followed by South America 24%, North America 8.2%, Africa 7.6%, Asia 3.8%, and Australia with 1.9% of all the replies. Figure 1 shows the countries participating in the study. And Table 1 and Figure 2 show Demographic characteristics of the respondents.

5.2. Rise of digital technology transformation on SD in HEIs

As shown in Figure 3, according to the respondents, the two areas that experienced the greatest acceleration of digital transformation during the pandemic were teaching, indicated by 52% of them, followed by research, mentioned by 24% of the sample. Outreach and organisations of events were mentioned by 11% and 10%, respectively.

Respondents were also asked to measure the extent to which new digital competences have been developed in response to the pandemic situation. The majority has indicated that it happens to some (39%) or to a great extent (34%). Figure 4 presents to which extent new digital competence were demanded as a response to COVID-19 pandemic.

Figure 1. Survey participating countries.
Source: Authors

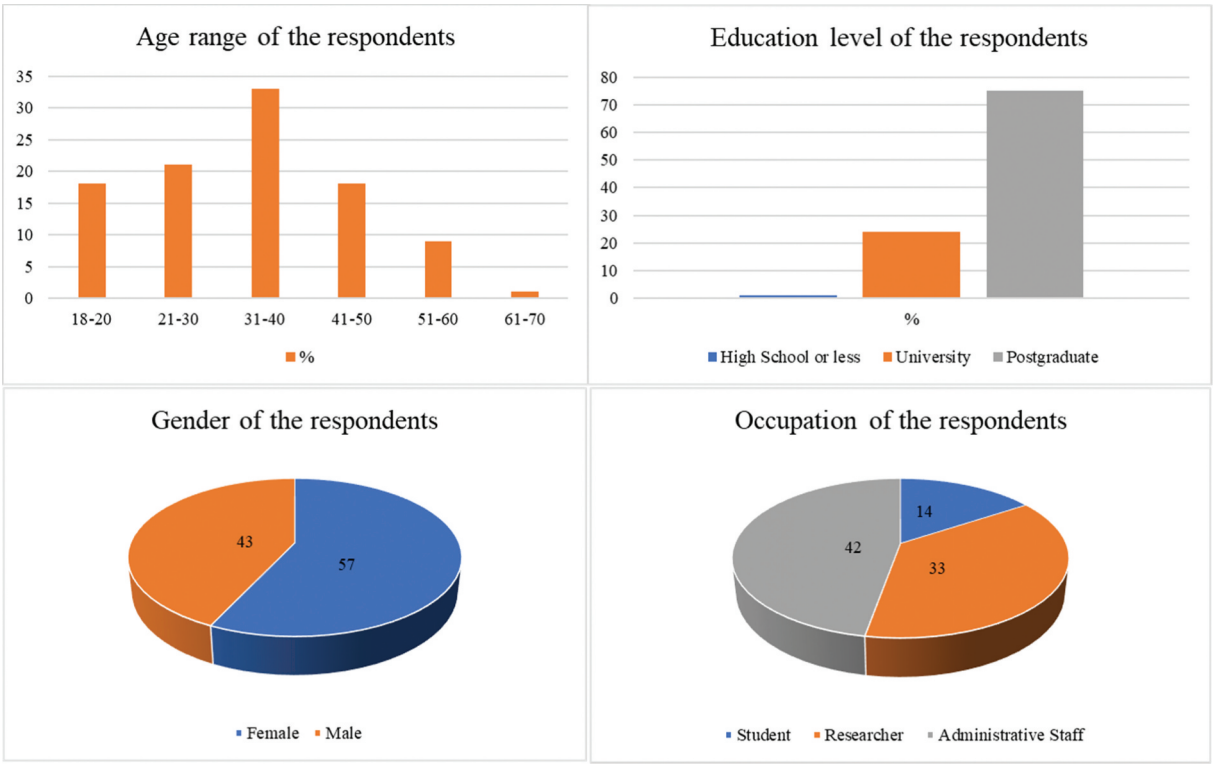

Figure 2. Demographic characteristics of the respondents.
Source: Authors

The results of the survey indicate that HEIs perceive the offer of training as an institutional responsibility to the extent that most of the respondents 64% received support from their university in acquiring new skills related to digital literacy, as presented in Figure 5. Of the 158 respondents, 30% reported that they acquired digital competence on their own, whereas 4% had to pay for their own training.

The survey investigated to what extent digital transformation can be deployed in a SD context – contributing to environmental, social and economic aspects. As shown in Figure 6, almost all respondents agreed that

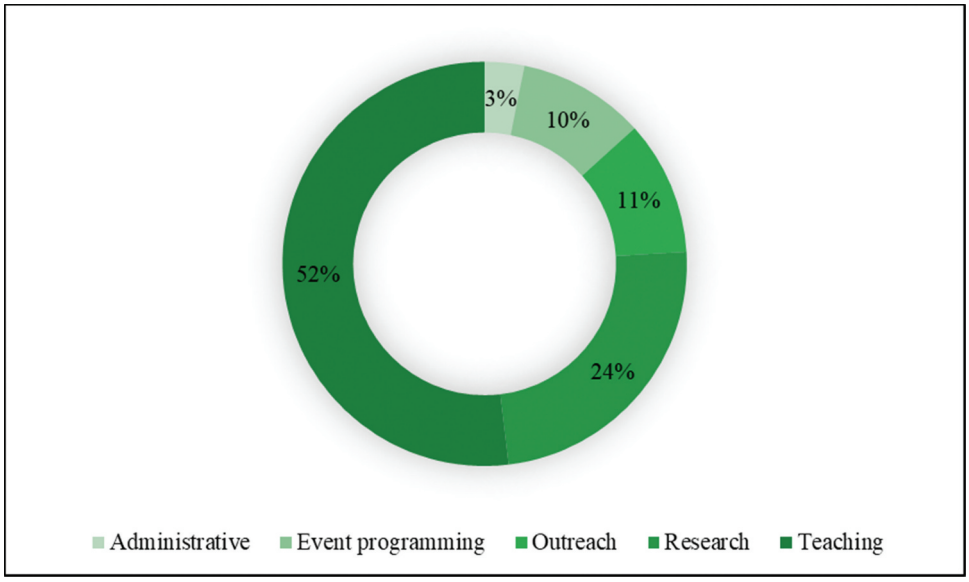

Figure 3. Areas in which the respondents have achieved greatest digital transformation due pandemic.
Source: Authors

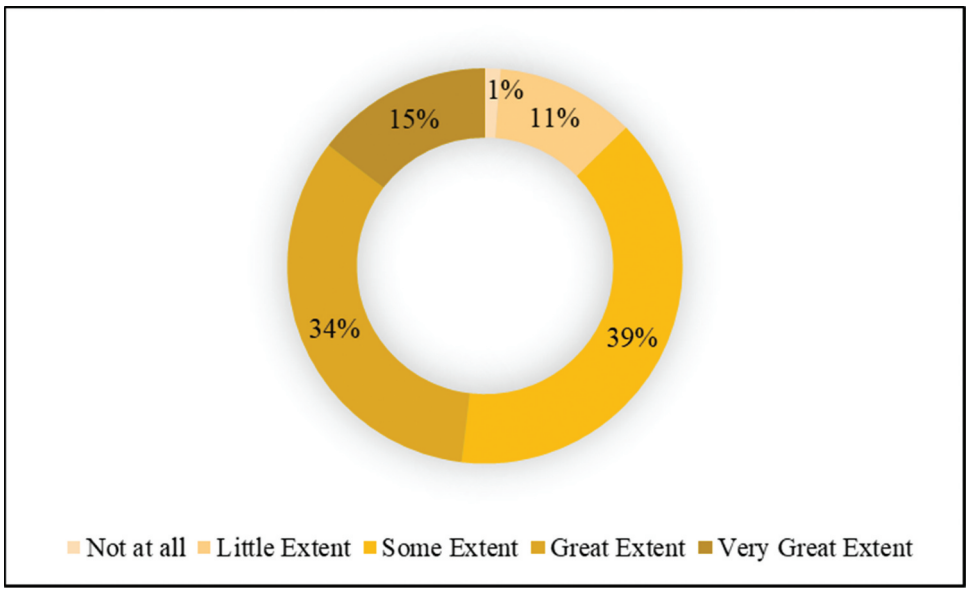

Figure 4. Extent to which new digital competence were demanded as a response to the COVID-19 pandemic.
Source: Authors

digital transformation can be pursued taking into consideration the SD aspects (99%, including responses from some, great and very great extent). No response has been received for the most negative response ('not at all'), which supports the favourite view of the respondents towards digital transformation.

5.3. Modelling the influence of digital technologies on SD

In the previous topic, an effort was made to explore how the growth of digital technologies took place amid the pandemic in higher education institutions and its relationship with SD. From this point onwards, the effort goes towards modelling the main determinants of digital literacy initiatives adopted during the pandemic to promote SD in HEIS.

The model was devised by utilizing questions from the survey that was administered, taking into account the relevant literature review (Kaputa et al., 2022; Staniec et al., 2022). Questions 7, 9 and 11 of the survey consisted of queries formulated in accordance with a five-point Likert scale. These specific questions were used for the development of the exploratory model, through PCA. The questionnaire was meticulously designed based on a thorough analysis of the existing literature and identified research gaps, with the objective of pinpointing information and knowledge

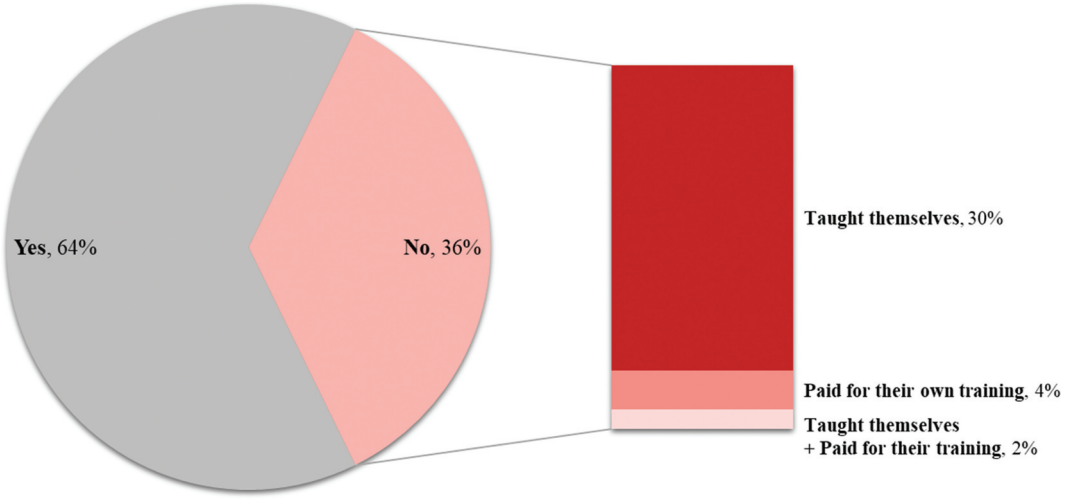

Figure 5. Acquisition of new digital competencies.
Source: Authors

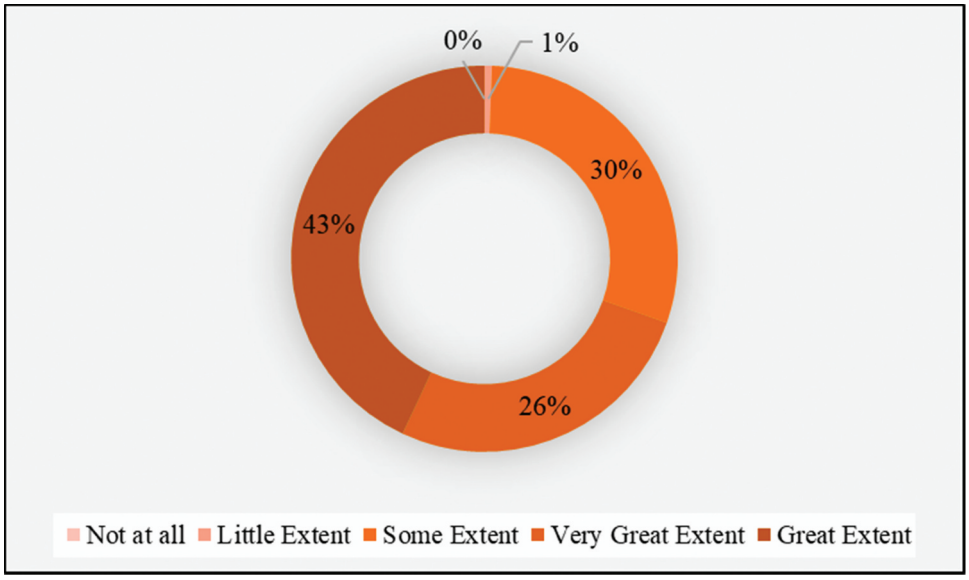

Figure 6. Extent to which digital transformation can be deployed in a SD context.
Source: Authors

deficiencies concerning digital transformation and SD. In this manner, the developed model confines itself to identifying the descriptors that influence digitization processes, examining their impact on fostering sustainable development in HEIs.

Thus, Table 2 condenses the main results of the principal component analysis performed to reveal the model's four components. The first column appears in bold and in uppercase the names of the components, followed by the items that compose them. From the second to the fifth column, the factorial loadings of the items for each of the four components are presented. Factorial loadings in shaded columns indicate which component each item belongs to. The last two columns report the mean and standard deviation for each component and each of the items comprising it. For example, as indicated in the first column, 'Component 1 - digital technology boosting sustainable development at HEIs' has five items. The factorial loadings of the items in this component range from .852 to .716, as illustrated in the second column, marked by the darkened shade. In the last two columns, it can be seen that the mean score for component 1 is 3.87, with a standard deviation of .93. In the five rows below are allocated the means and standard deviation for each of the items aggregated to component 1. The last three rows of Table 2 show the eigenvalue of the rotated varimax solution for each component, the percentage of the variance of squared loadings, and the reliability test result, calculated through Cronbach's Alpha.

Thus, employing the latent root criterion, the following four components achieved the threshold of

Table 1. Demographic characteristics of the respondents.

Age Range (158)	n	%	Educational Level (158)	n	%
18–20	29	18	High School or less	1	1
21–30	33	21	University	38	24
31–40	52	33	Postgraduate	119	75
41–50	29	18			
51–60	14	9			
61–70	2	1			
Gender (158)	**n**	**%**	**Occupation (199) ***	**n**	**%**
Female	90	57	Student	28	14
Male	68	43	Researcher	66	33
			Administrative Staff	105	42

Note: * Multiple choice.
Source: Authors.

eigenvalues greater than one: 1 - digital technology boosting sustainable development at HEIs; 2 - digital tools boosting innovative business opportunity; 3 - digital tools boosting innovative ideas; and – need to improve digital technologies at HEIs. The sum of the variance allocated in the model explains 71.26% of the total variance of the 14 items allocated in the designed model.

The overall MSA and the MSA of each item and Bartlett's sphericity test were employed to assess the feasibility of applying the model. To assess the model's reliability, Cronbach's Alpha was used. The global MSA was .731, and items ranging from .543 to .908 were more significant than the cut-off limits (Field 2018). The Bartlett's test of sphericity results significative ($X^2_{(91)} = 1243{,}270$, $p = .000$). The reliability test results in an acceptable Cronbach's Alpha for each component ranging from .700 to .898 (Hair et al. 2014).

The first component in Table 2, 'Digital technology boosting sustainable development at HEIs', has the second highest average value among the model components (3.87). It deals with the potential of digital transformations have to bring varied benefits to HEIs in implementing sustainability initiatives. Consistent with this study, Kaputa et al. (2022) acknowledge that digital technology equips HEIs with the essential tools and competencies to address contemporary global challenges, such as SD, from a transdisciplinary perspective.

The second and third components, described in Table 2, look at the potential for digital tools to drive 'business opportunities' and 'innovative ideas', respectively, which is done by analysing whether the sample of respondents developed or took part in business opportunities (2.54) or in the implementation of innovative ideas (3.21) before, during or after the pandemic of COVID-19. These two components had the lowest mean scores in the model Ciasullo and Lim (2022) recognise that the pervasive digitalisation phenomenon has created new opportunities for innovative business model (IBM). However, the authors assert that digitalisation encompasses more than simply implementing various digital technologies as tools. Instead, digital transformation within HEIs represents a complex phenomenon that necessitates a broader and more profound re-evaluation of processes. This re-evaluation may require acquiring new skills and entail a significant investment of human energy and time (Kaputa et al., 2022). These barriers reported in the literature, related to implementing organisational digitisation processes, may justify the low scores achieved in the two components mentioned above.

When respondents were asked whether they had acquired the ability to develop a digitally-based IBM on SD during the COVID-19 pandemic, 32% said yes, and 67% said no. As shown in Figure 7, this skill is influenced by each of the latent variables (components) identified in the model (Table 2). The values in Figure 7 correspond to each component's 'yes' and 'no' average measures. Respondents who reported that they had not acquired skills to develop IBM assigned lower values for components 1, 2 and 3, and the difference is statistically significant for components 2 ($t_{(156)} = 9.859$, $p = .000$) and 3 ($t_{(156)} = 2.911$, $p = .001$).

The fourth component, entitled 'need to improve digital technologies at Higher Education Institutions', is formed by three items and obtained the highest average among the components of the model (4.13), indicating that despite the advances detailed above, the respondents recognise that there is still much to be done for HEIs to achieve digital literacy aimed at SD.

Prior to the onset of the pandemic, which served as a catalyst for expediting digitisation endeavours, Khalid et al. (2018) recognised a prevalent fallacy surrounding digitisation, wherein new techniques and tools were erroneously perceived as applicable solely to business processes. The authors emphasise the imperative of implementing these technologies across all levels of an institution, particularly in the context of HEIs. They underscore the significance of HEIs comprehending the broader scope of digitisation and its associated advantages. In this regard, the authors assert that comprehensive transformation initiatives spanning multiple departments should be primarily driven by beneficiaries while concurrently supported by the IT department equipped with upgraded technology. This collaborative approach is deemed indispensable for achieving sustainable outcomes.

Table 2. Modelling and assessment of digital technologies over SD at HEIS (PCA and Reliability Analysis).

	Component loads				Descrip. Statistic	
	1	2	3	4	Mean	SD
COMPONENT 1 – DIGITAL TECHNOLOGY BOOSTING SUSTAINABLE DEVELOPMENT at HEIs					**3.87**	**.93**
The implementation of timely and properly designed digitally-based technologies at HEIs green stimulus measures can deliver economic and environmental benefits	.852	.115	.081	.094	3.92	.881
Digital transformation can strengthen environmental sustainability and reduce vulnerability to the current and future pandemics	.826	.096	.014	.087	3.86	.934
Leveraging digital technologies may accelerate progress towards the implementation of the SDGs	.801	.139	-.021	.339	3.79	.984
Leveraging digital technologies may facilitate teaching and research on the SDGs	.731	.046	.043	.211	3.82	.954
Digital transformation can strengthen governance practices and policy coherence at HEIs for sustainable development	.716	.015	.239	.256	3.94	.886
COMPONENT 2 - DIGITAL TOOLS BOOSTING BUSINESS OPPORTUNITY					**2.54**	**1.14**
I have been able to pursue innovative business opportunities on SD using digital tools during the COVID-19 pandemic	.170	.904	.206	-.013	2.63	1.208
I have been able to pursue innovative business opportunities on SD using digital tools in the aftermath of the COVID-19 pandemic	.180	.896	.169	-.073	2.66	1.204
I have been able to pursue innovative business opportunities on SD using digital tools before the COVID-19 pandemic	-.007	.836	.227	.043	2.34	1.013
COMPONENT 3 - DIGITAL TOOLS BOOSTING INNOVATIVE IDEAS					**3.21**	**.940**
I have been able to develop innovative ideas around sustainability issues using digital means during the COVID-19 pandemic	.160	.105	.886	.011	3.42	.953
I have been able to develop innovative ideas around sustainability issues using digital means in the aftermath of the COVID-19 pandemic	.190	.220	.777	-.052	3.41	.984
I have been able to develop innovative ideas around sustainability issues using digital means before the COVID-19 pandemic	-.106	.265	.705	.025	2.79	.875
COMPONENT 4 - NEED TO IMPROVE DIGITAL-TECH at HEIs					**4.13**	**0.91**
There is need to improve the sustainability dimension of teleworking, remote learning and virtual living	.211	-.082	.014	.780	4.22	.960
Limitations in digital connectivity disproportionately affects students, and those in precarious or informal jobs	.146	-.045	-.081	.778	4.22	.824
Enhancing the use of digital technologies will be critical for a resilient and sustainable COVID-19 pandemic	.381	.122	.083	.682	3.95	.943
Eigenvalue (rotated solution, varimax)	3.440	2.517	2.089	1.931		
% of Variance of Squared Loadings	24.569	17.976	14.918	13.793		
Reliability analysis (Cronbach's Alpha)	.879	.898	.760	.700		

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 6 iterations.
Source: Authors.

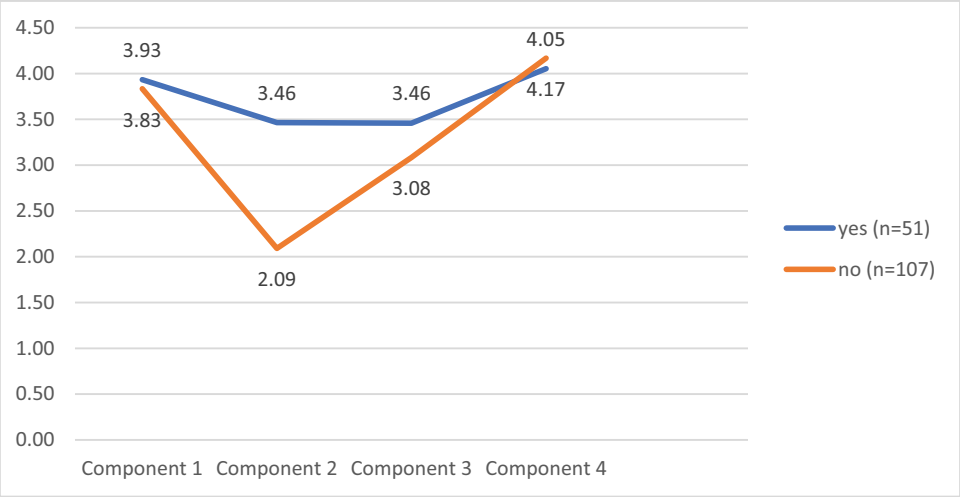

Figure 7. Ability to design digitally-based innovative business models on SD during the COVID-19 pandemic. Source: Authors

5.4. Challenges and future expected regarding digital transformation on HEIs

To further understand future challenges regarding digital transformation on HEIs, the respondents were asked to list the categories in which they see maximum potential. The most important category emerged to be 'Digital technologies in sustainability teaching' (n = 122, 77%), followed by 'Digital technologies in sustainability-oriented innovation' (n = 103, 65%), 'Digital technologies in works with external stakeholders' (n = 93, 59%) and Digital technologies in sustainability research (n = 91, 58%). It is interesting to point out that even though multiple responses were possible 'Digital technologies in sustainability teaching' (n = 122, 24.94%) was considered more central to the future than Digital technologies in sustainability research (n = 91, 18,60%).

The respondents were also asked to identify the main challenges for digital transformation which were mainly accelerated by the COVID-19 pandemic. The replies were varied, and the top three challenges included: time management skills in lockdown/home office situations (n = 97, 61%), 'learn how to use (new) digital tools' (n = 94, 59%) and 'continue the development of academic networking/conferences (n = 89, 56%). It is interesting to point out that the category 'protection from technostress and related health issues achieved relatively low scores (n = 43, 27%).

Respondents also had the opportunity to voice their experience with digital transformation during the COVID-19 pandemic aiming at SD in higher education, through an open-ended question. There were 27 written replies with the focus being on the accelerated rate at which academic staff from different geographic regions managed to utilise digital tools, in teaching and research situations. The below three verbatim statements illustrate the rather narrow range of replies received.

'The pandemic has stipulated staff members to learn new digital tools. Even those who were very resistant to use technologies, made a try and even were successful in use of technologies, even the senior staff members'.

(Professor, Brazil)

Together with lecturers from other countries we developed several 'virtual exchange' opportunities for students, by arranging joint group assignments with students from 2 different institutions.

(Senior lecturer, Canada)

It changed the way we give classes completely; it also facilitated the inscription and attendance of students; and there is a growing consensus that in the future we should combine bi-learning methods and techniques.

(Professor, Latvia)

6. Discussion

This study shows that changes in digital technology have been reported in all academic areas, as most of the world's educational systems have experienced long periods of disruption in face-to-face activities. This is confirmed by Kerres (2020) who stated that in times of Covid-19, lectures are looking for digital tools to provide learning materials to their students and manage communication on the sphere of their online classes.

Similarly, in the work of Leal Filho et al. (2021), that analysed the impact of pandemic on SD teaching, it was noticed that the shutdown had forced the academic community to use a variety of digital technologies to deliver teaching activities amid the global crisis. The study also pointed out the issues faced by lectures regarding the radical changes in daily work routines they had to perform, in a very short time, to adapt the content and method of their lectures to the new

circumstances. Regarding the field of research, as claimed by Rashid and Yadav (2020) universities and institutions devoted to research are dealing huge challenges in keeping the research operations. The required physical distancing is incompatible with many of the day-to-day research activities, especially those that demand bench work, human subjects, along with field work. According to the mentioned authors (Rashid and Yadav 2020), it has been causing substantial losses in activities related to research. The present study suggests that the academic community in HEIs has been reflecting and finding ways to overcome the crises through digital transformation technology (Figure 4), especially in teaching activities.

However, those involved in higher education do not seem to be familiar with the new digitial activities of HEIs. These difficulties of those involved were placed under the term Digital Literacy which is defined in the paper of Tejedor et al. (2020, p. 4) as the 'acquisition of the technical competence for using information and communication technologies, understood in a broad sense, in addition to the acquisition of the basic practical and intellectual capacities for individuals to completely develop themselves in the Information Society'. As referred by Kerres (2020) many lectures have been accelerating their learning of digital competences to cope the challenges of distance learning emerged due to the COVID-19 pandemic. Our study corroborates these views, as not only have the respondents indicated a high level of demand of digital competence to deal with the pandemic (Figure 5), but also had to teach themselves or pursue specific trainings (Figure 6).

The need to intensify the learning of digital skills (as depicted in Figure 5), suggests that the academic professionals are facing an increase in the load of their daily labour (either by the potential increase of required tasks or by the demand to take time to develop these skills). This argument is in line with the study by Leal Filho et al. (2021), according to which most of the teachers surveyed reported a moderate (42%) or great (31%) increase on their workload.

In the literature, there is a concern regarding the shortcomings in using e-learning available tools. Rashid and Yadav (2020) stress the 'need for more training of educators in digital technology to adapt to the rapidly changing education climate of the world'. Our investigation also supports this concern, as shown in Figure 6.

The positive effect of digitalization on SD (Figure 7) is reported in literature describing cases in several areas of knowledge, such as urban cities (Balogun et al. 2020), urban transport system (Creutzig et al. 2019), medicine (Ting et al. 2020), to cite a few. On the subject of digitalization technologies in the field of higher education institutions (Giesenbauer and Müller-Christ 2020) have developed an integrative framework that considers the digitalization initiatives on governance, management, operations and learning as a key aspect to deal with the increasing complexity to meet the challenger of SD in HEIs.

The analysis that supports Table 2 is in line with several studies related to digitalization for the promotion of SD. For example, Burbules et al. (2020) recognise the provision of quality education as a fundamental prerequisite for the achievement of the others SDGs. According to the author, educational systems must incorporate the newest information technologies to increase productivity and system quality, transforming educational institutions into sites of

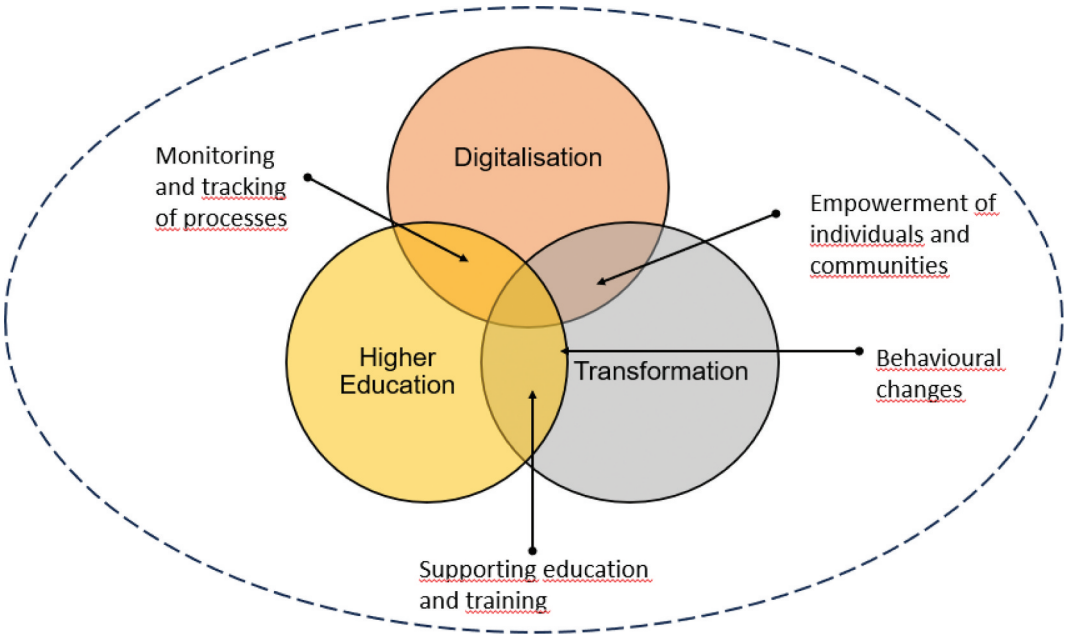

Figure 8. Connections between the various elements. Source: Authors

critical collaborative inquiry and autonomous sustainable learning, in which individuals and groups might operate new technologies to solve authentic problems. In the field of governance to SD, Giesenbauer and Müller-Christ (2020) advocate that HEIs engaged in a mature, digitalized and integrative approach designate themselves as a space focused in systematic solutions, co-creativity and sustainability that encourage physical and virtual integration of different societal and ecological systems.

Another gain in accelerate the implementation of digital transformations understanding the needs of industry for future digital skills in education is reported by Joshi (2021) that recognizes the potential of helping HEIs to build the future-ready digital workforce to assume skilled jobs in industry 4.0 establishing a soft power of medium and long term in the post COVID world.

The response pattern in Figure 8 highlights the importance of promoting institutional programmes of training and developing a culture aimed at encouraging innovation through the adoption of digital tools in HEIs as it is suggested by Giesenbauer and Müller-Christ (2020).

Digitalization is in fact one of the main challenges identified for higher education institutions to act as key change agents for sustainable development (Giesenbauer and Müller-Christ 2020). This is also supported by other studies that point out that the need to improve the digital sustainable development in teaching in higher education, will necessitate the overcoming of profound challenges (Sá and Serpa 2020).

Figure 8 showcases the connection between the various key elements: digitalisation, transformation, sustainability, and higher education.

It is apparent that digital technologies in education allow the transition and foster the challenge to move on from individualised learning to communities of practice that necessitate different and new skills, key to succeed in the digital future (Zermeño and Massive 2020). The findings of this investigation appear to be expected as the shift to e-learning or b-learning is inescapable (Cheema 2020).

The novelty of the paper resides on the fact that it outlines the connections between digitalisation and SD at HEIs. Also, it identifies the elements which influence digitalisation on SD and lists some of the barriers associated with this process.

This paper has some limitations. The first one is associated with the small number of respondents and the use of a narrow definition for SD. In addition, some geographical regions such as Africa and Asia were not well represented. As questionnaire-based surveys in different countries were made more difficult to conduct during the pandemic, it is believed that this could have an impact on the size of the sample. As a result, although the study draws information from a diverse sample of respondents (158 completed questionnaires from 39 countries), the findings do not cater for a wide generalisation of trends. The sample here-as it is the case of all surveys- is a cluster of people that represent a larger group of interest. In this case, staff at HEIs interested enough on SD to engage with the survey. As it is widely known, surveying a large part of (or even the entire) target population of interest is simply not possible due to the large number of people that comprise it. Therefore, by a surveying sample of the population instead, researchers may be in a position to make inferences about and identify insights into the behaviours and opinions of the larger target population. This is what this study achieved. So, the sample limitation is not exclusive of this study, it applies to all surveys.

It is worth noting that these limitations provide fertile ground for future studies to delve deeper in these issues through relevant quantitative and/or mixed methods approaches. Despite its limitations, the sample serves the purpose of providing a rough profile of trends related to digitization on SD at HEIs. It also illustrates the need for further studies, for instance on whether digital transformation is affecting the 17 SDGs and how HEIs can play a pivotal role in endorsing the global goals through digital technologies.

7. Conclusions

This research examines the challenges regarding digital transformation in higher education and underlying effects of endorsements of SD in HEIs. The COVID-19 pandemic stimulated a rapid acceleration of digital transformation in HEIs, especially in teaching and research processes. A common practice in the examined academic institutions is the wide adoption of distance-learning procedures in order to meet the fundamental teaching needs of students.

The success of these fast-paced digital transformations needs to be supported by specific skills and competences of academic and administrative staff members. The majority of respondents seem to develop digital skills and increase their regular involvement with e-learning and distance-learning platforms, tasks and applications. Certainly, in this way, their daily workload has increased significantly, and findings also reveal that the participants need more digital training, which some received on their own and some claimed that it was provided by fast-track training webinars or webcasts organized by their HEIs. Some significant challenges identified are the required time management skills in lockdown/home-office situations, the urgent need to learn how to use (new) digital tools and continue the active engagement in academic networking/conferences.

Another significant finding of this research pertains to the effect of digitalization on SD at HEIs. Respondents seem to support the fact that digital transformation is useful to promote SD. In particular, the findings suggest

that digital technologies could boost SD at HEIs as enabling conditions are shaped and allow to achieve fundamental SD principles. The findings point out to the need for an institutional-oriented approach regarding the promotion of digitalization of HEIs. The majority of respondents claim that they had not acquired certain skills to develop digitally based IBMs on SD during the COVID-19 pandemic. In this respect, they emphasize the role of institutions in stimulating HEI training programmes and to promote innovation through digital tools.

Lastly, the overall results confirm that there is plenty of room for HEIs to achieve robust and effective digital transformation to promote SD principles, transitions, and trajectories. Some significant practices could be the diffusion of digital technologies to teach sustainability challenges, to create the necessary conditions for sustainability-oriented innovation, to strengthen and facilitate collaboration with external stakeholders, and to facilitate more research projects on sustainability-focused thematic areas and issues.

Overall, the implications of the paper are two-fold. Firstly, it provides a welcome addition to the literature on the implications of digitalisation to SD practices. Secondly, it describes some of the needs identified by staff at HEIs, and some of the measures, which may be deployed by staff at universities, in order to address digitization in a SD context, allowing HEIs to take advantages of the many opportunities if may offer.

Note

1. Inter-University Sustainable Development Research Programme (IUSDRP, https://www.haw-hamburg.de/en/ftz-nk/programmes/iusdrp/), a global network of universities committed to sustainability research.

Acknowledgments

This paper is part of the "100 papers to accelerate the implementation of the UN Sustainable Development Goals" initiative.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Anonymous treatment of respondents and ethical statement

The full questionnaire was designed to collect general information and ensure that details were anonymous. According to the German law, the study is exempted from ethical approval.

References

Abad-Segura E, González-Zamar M-D, Infante Moro JC, Ruipérez García G. 2020. Sustainable management of digital transformation in higher education: global research trends. Sustainability. 12(5):2107. doi: 10.3390/su12052107.

Adedoyin OB, Soykan E. 2020. Covid-19 pandemic and online learning: the challenges and opportunities. Interact Learn Env. 31(2):863–875. doi: 10.1080/10494820.2020.1813180.

Ahel O, Lingenau K. 2020. Opportunities and challenges of digitalization to improve access to education for sustainable development in higher education bt - universities as living labs for sustainable development: supporting the implementation of the sustainable development goals. eds. Walter Leal Filho et al. Cham: Springer International Publishing; pp. 341–356. 10.1007/978-3-030-15604-6_21

Arlinwibowo J, Retnawati H, Kartowagiran B, Kassymova GK. 2020. Distance learning policy in Indonesia for facing pandemic COVID-19: school reaction and lesson plans. J Theor Appl Inf Technol. 98(14): 2828–2838.

Association for Learning Technology. 2020. ALT responds to digital teaching and learning during the coronavirus pandemic: call for evidence.

Azeiteiro U, Bacelar Nicolau P, Caetano F, Caeiro S. 2015. Education for sustainable development through e-learning in higher education: experiences from Portugal. J Clean Prod. 106:308–319. doi: 10.1016/j.jclepro.2014.11.056.

Balogun A-L, Marks D, Sharma R, Shekhar H, Balmes C, Maheng D, Arshad A, Salehi P. 2020. Assessing the potentials of digitalization as a tool for climate change adaptation and sustainable development in Urban centres. Sustain Cities Soc. 53 ISSN 2210-6707:101888. doi:10.1016/j.scs.2019.101888

Berchin II, de Andrade JBSO. 2020. GAIA 3.0: effects of the coronavirus disease 2019 (COVID-19) outbreak on sustainable development and future perspectives. Res Glob. 2:100014. doi:10.1016/j.resglo.2020.100014.

Bond M. 2020. Schools and emergency remote education during the COVID-19 pandemic: A living rapid systematic review. Asian JDistance Educ Bond. 15(2): 191–247.

Bozkurt A. 2020. Educational technology research patterns in the realm of the digital knowledge age. JIME. 2020(1):18. doi: 10.5334/jime.570.

Brundtland Commision. 1987. Our future common report. Brundtland.

Burbules NC, Fan G, Repp P. 2020. Five trends of education and technology in a sustainable future. Geogr Sustain. 1 (2):93–97. doi: 10.1016/j.geosus.2020.05.001.

Carayannis EG, Morawska-Jancelewicz J. 2022. The futures of europe: society 5.0 and industry 5.0 as driving forces of

future universities. J Knowl Econ. 13(4):3445–3471. doi: 10.1007/s13132-021-00854-2.
Castro MP, Zermeño MGG. 2020. Challenge based learning: innovative pedagogy for sustainability through e-learning in higher education. Sustainability. 12(10):4063. doi: 10.3390/su12104063.
Cheema MS. 2020. COVID-19 revolutionising higher education: an educator's viewpoint of the challenges, benefits and the way forward. Life Sci Med Biomed. 4(9]):1–6. doi: 10.28916/lsmb.4.9.2020.61.
Ciasullo MV, Lim WM. 2022. Digital transformation and business model innovation: Advances, challenges and opportunities. Int. J. Qual. Innov. 6:1.
Creutzig F, Franzen M, Moeckel R, Heinrichs D, Nagel K, Nieland S, Weisz H. 2019. Leveraging digitalization for sustainability in urban transport. Glob Sustain. 2:e14. doi:10.1017/sus.2019.11.
Daniel SJ. 2020. Education and the COVID-19 pandemic. Prospects. 49(1–2):91–96. doi: 10.1007/s11125-020-09464-3.
de Amorim WS, de Andrade Guerra JBSO. 2020. Pandemics, global risks and adaptation: Challenges for a changing world. Res Glob. 2:100023. doi: 10.1016/j.resglo.2020.100023. Epub 2020 Sep 30. PMCID: PMC7526594.
Del Olmo MA, Sánchez JS. 2019. El desarrollo sostenible como reto pedagógico de la universidad del siglo XXI. Anduli. 19(19):59–80. doi: 10.12795/anduli.2020.i19.03.
Del Río Castro G, Fernández MCG, Colsa AU. 2021. Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. J Clean Prod. 280(1):122204. doi: 10.1016/j.jclepro.2020.122204.
Estermann B, Fivaz J, Frecè J, Harder D, Jarchow T, Wäspi F 2020. Digitalisierung und Umwelt: Chancen, Risiken und Handlungsbedarf. Ergebnisse einer Studie im Auftrag des Bundesamtes für Umwelt. [accessed 2021 July 16] https://www.bfh.ch/.documents/ris/2018-147.145.061/BFHID-1109007316-8/BAFU-Studienbericht-final-2020-04.pdf.
Field A. 2018.Discovering statistics using IBM SPSS statistics. 5th ed. J. Seaman, Ed. London: SAGE Publications.
Fletcher G, Griffiths M. 2020. Digital transformation during a lockdown. Int J Inf Manage. 55:102185. doi: 10.1016/j.ijinfomgt.2020.102185.
Foundation Education Endowment. 2020. Remote learning. Encyclopedia of Education and Information Technologies. pp. 1427–1427.
Gapsalamov A, Bochkareva T, Vasilev V, Akhmetshin E, Anisimova T. 2020. Comparative analysis of education quality and the level of competitiveness of leader countries under digitalization conditions. J Soc Stud Educ Res. 10(2):133–150. https://www.learntechlib.org/p/217549/.
Giesenbauer B, Müller-Christ G. 2020. University 4.0: promoting the transformation of higher education institutions toward sustainable development. Sustainability. 12(8):3371. doi: 10.3390/su12083371
Goswami S. 2014 Jan-Mar. ICT: sustainable development. SCMS J Indian Manag; Kochi. 11(1):125–133.
Gouvea R, Kapelianis D, Kassicieh S. 2018. Assessing the nexus of sustainability and information & communications technology. Technol Forecast Soc. 130:39–44. doi: 10.1016/j.techfore.2017.07.023.
Habib MN, Jamal W, Khalil U, Khan Z. 2021. Transforming universities in interactive digital platform: case of city university of science and information technology. Educ Inf Technol. 26(1):517–541. doi: 10.1007/s10639-020-10237-w.
Hair JJF, Black WC, Babin BJ, Anderson RE. 2014. Multivariate data analysis. 7a ed. Essex: Pearson.
Hair J, Celsi MW, Money AH, Samouel P, Page MJ. 2011. Essentials of business research methods. 2nd ed. New York: Routledge. doi: 10.4324/9781315704562.
Hák T, Janoušková S, Moldan B. 2016. Sustainable development goals: A need for relevant indicators. Ecol Indic. 60(1):565–573. doi: 10.1016/j.ecolind.2015.08.003
Henry C. 2012. ICT for sustainable development. Sci Technol. 2(5):142–145. doi: 10.5923/j.scit.20120205.06.
Hess T, Matt C, Benlian A, Wiesboeck F. 2016. Options for formulating a digital transformation strategy. Mis Q Exec. 15(2):123–139. https://boris.unibe.ch/id/eprint/105447
Hilty LM, Aebischer B. 2015. ICT for sustainability: an emerging research field. In: Hilty LM Aebischer B editors. ICT innovations for sustainability, advances in intelligent systems and computingVol. 310. Cham: Springer. pp. 3–36. doi: 10.1007/978-3-319-09228-7_1
IAU & ESN. 2020. COVID-19 impact on higher education: institutional and students. Perspectives. 3.
Iivari N, Sharma S, Ventä-Olkkonen L. 2020. Digital transformation of everyday life–how COVID-19 pandemic transformed the basic education of the young generation and why information management research should care? Int J Inf Manage. 55:102183. doi: 10.1016/j.ijinfomgt.2020.102183.
Jakoet-Salie A, Ramalobe K. 2023. The digitalization of learning and teaching practices in higher education institutions during the covid-19 pandemic. Teach Public Adm. 41(1):59–71. doi: 10.1177/01447394221092275
Joshi S. 2021. Rising importance of remote learning in India in the wake of COVID-19: issues, challenges and way forward. World J Sci Technol Sustain Dev. 18(1):44–63. doi: 10.1108/WJSTSD-10-2020-0079.
Kaputa V, Loučanová E, Tejerina-Gaite FA. 2022. Digital transformation in higher education institutions as a driver of social oriented innovations. In: Păunescu C, Lepik K-L, and Spencer N, editors. Social innovation in higher education: Landscape, practices, and opportunities. Springer International Publishing; p. 61.
Kerres M. 2020. Against all odds: education in germany coping with covid-19. Postdigital Sci Educ. 2(3):690–694. doi: 10.1007/s42438-020-00130-7.
Khalid J, Rahul Ram B, Soliman M, Ali AJ, Khaleel M, Islam Md S. 2018. Promising digital university: a pivotal need for higher education transformation. International Journal of Management in Education. 12(3):264–275. doi: 10.1504/IJMIE.2018.092868.
Kolk A. 2016. The social responsibility of international business: from ethics and the environment to CSR and sustainable development. J World Bus. 51(1):23–34. doi: 10.1016/j.jwb.2015.08.010
Lai J, Widmar NO. 2020. Revisiting the digital divide in the COVID-19 era. Appl Econ Perspect Policy. 43(1):458–464. doi: 10.1002/aepp.13104.
Leal Filho W, Amaro J, Avila LV, Brandli L, Damke L, Vasconcelos CRP, Hernandez-Diaz P, Frankenberger F, Fritzen B, Velazquez L, et al. 2021. Mapping sustainability initiatives in higher education institutions in Latin America. J Clean Prod. 315:128093. doi:10.1016/j.jclepro.2021.128093.
Leal Filho W, Azul AM, Wall T, Vasconcelos CRP, Salvia AL, Do Paço A, Shulla K, Levesque V, Doni F, Alvarez-Castañón L, et al. 2021. COVID-19: the impact of a global crisis on sustainable development research. Sustain Sci. 16(1):85–99. doi:10.1007/s11625-020-00866-y.
Leal Filho W, Price E, Wall T, Shiel C, Azeiteiro UM, Mifsud M, Brandli L, Farinha CS, Caeiro S, Salvia AL, et al. 2021. COVID-19: the impact of a global crisis on sustainable

development teaching. Environ Dev Sustain. 23 (8):11257–11278. doi:10.1007/s10668-020-01107-z.
Lee O-K, Sambamurthy V, Lim KH, Wei KK. 2015. How does IT ambidexterity impact organizational agility? Inf Syst Res. 26(2):398–417. doi: 10.1287/isre.2015.0577
Li C, Lalani F. 2020. The COVID-19 Pandemic Has Changed Education Forever. This is How. https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning
Loveless A, DeVoogd GL, Bohlin RM. 2001. Something old, something new...Is pedagogy affected by ICT? In: Loveless A, and Ellis V, editors ICT, pedagogy and the curriculum. London: Routledge; p. 21.
Majchrzak A, Markus ML, Wareham J. 2016. Designing for digital transformation: lessons for information systems research from the study of ICT and societal challenges. Mis Q. 40(2):267–277. doi: 10.25300/MISQ/2016/40:2.03.
Malhotra NK, Nunan D, Birks DF. 2018. Marketing research: an applied approach. Fifth ed. Edinburgh: Pearson Education Limited.
Mensah J, Ricart Casadevall S. 2019. Sustainable development: meaning, history, principles, pillars, and implications for human action: literature review. Cogent Soc Sci. 5 (1):1653531. doi: 10.1080/23311886.2019.1653531.
Mergel I, Edelmann N, Haug N. 2019. Defining digital transformation: results from expert interviews. Gov Inf Q. 36(4): doi: 10.1016/j.giq.2019.06.002.
Michalsen A, Vergano M, Quintel M, Sadovnikoff N, Truog RD. 2020. Epilogue: critical care during a pandemic – a shift from deontology to utilitarianism? In Compelling ethical challenges in critical care and emergency medicine. Springer International Publishing; pp. 157–166. doi: 10.1007/978-3-030-43127-3_16.
Nambisan S, Wright M, Feldman M. 2019. The digital transformation of innovation and entrepreneurship: progress, challenges and key themes. Res Policy. 48(8):103773. doi: 10.1016/j.respol.2019.03.018
Noy C. 2008a. Sampling knowledge: the hermeneutics of snowball sampling in qualitative research. Int J Soc Res Methodol. 11(4): doi: 10.1080/13645570701401305.
OECD/European Union. 2019. Supporting Entrepreneurship and Innovation in Higher Education in Italy, OECD Skills Studies. Paris: OECD Publishing. doi: 10.1787/43e88f48-en.
Ramij Md G, Sultana A. 2020. Preparedness of online classes in developing countries amid COVID-19 outbreak: A perspective from bangladesh (june 29). SSRN Electron J. doi: 10.2139/ssrn.3638718.
Rashid S, Yadav SS. 2020. Impact of covid-19 pandemic on higher education and research. Indian J Hum Dev. 14 (2):340–343. doi: 10.1177/0973703020946700
Reis J, Amorim M, Melão N, Matos P 2018. Digital Transformation: A Literature Review and Guidelines for Future Research. In: Rocha Á, Adeli H, Reis LP, and Costanzo S, editors. Trends and Advances in Information Systems and Technologies. WorldCIST'18 2018. Advances in Intelligent Systems and Computing. Vol. 745. Cham: Springer. doi: 10.1007/978-3-319-77703-0_41.
Saliba M. 2020. Getting to grips with online conferences. Nat Energy. 5:488–490. doi: 10.1038/s41560-020-0656-z.
Sá MJ, Serpa S. 2020. The COVID-19 pandemic as an opportunity to foster the sustainable *development of teaching in higher education*. Sustainability. 12(20):8525. doi: 10.3390/su12208525.
Sobrosa Neto RC, Maia JS, Neiva SS, Scalia DS, Guerra JBSOA. 2020. The fourth industrial revolution and the coronavirus: a new era catalyzed by a vírus. Res Glob. 2:100024. doi:10.1016/j.resglo.2020.100024.
Staniec I, Kaczorowska-Spychalska D, Kalinska-Kula M, Szczygiel N. 2022. The study of emotional effects of digitalized work: the case of higher education in the sustainable development. Int J Environ Res Public Health. 19 (1):576. doi: 10.3390/ijerph19010576.
Szűts Z, Molnár G, Racsko R, Vaughan G, Molnár TL. 2023. Pedagogical Implications and Methodological Possibilities of Digital Transformation in Digital Education after the COVID-19 Epidemic. Computers. 12(4):73. doi: 10.3390/computers12040073.
Tejedor S, Cervi L, Pérez-Escoda A, Jumbo FT. 2020. Digital literacy and higher education during COVID-19 lockdown: spain, italy, and ecuador. Publications. 8(4):48. doi: 10.3390/publications8040048
Ting DSW, Carin L, Dzau V, Wong TY. 2020. Digital technology and COVID-19. Nat Med. 26(4):459–461. doi: 10.1038/s41591-020-0824-5.
Trinkūnienė S, Juskaite L 2021. COVID-19 and the digital transformation of education: the case of latvia and lithuania. *SOCIETY. INTEGRATION. EDUCATION*, Proceedings of the International Scientific Conference. Volume V, May 28th-29th, 221–231. 10.17770/sie2021vol5.6429
UNDP. 2011. Human development report 2011: sustainability and equity - a better future for all. New York
United Nations. 2015. Transforming our world: the 2030 agenda for sustainable development. New York, United Nations: sustainabledevelopment.un.org.
Unwin T. 2009. ICT4D: information and communication technology for development. Cambridge: Cambridge University Press.
Vallez M, Lopezosa C, Pedraza-Jiménez R. 2022. A study of the web visibility of the sDGs and the 2030 agenda on university websites. Int J Sustain Higher Educ. 23(8):41–59. doi: 10.1108/IJSHE-09-2021-0361.
Verhoef PC, Broekhuizen T, Bart Y, Bhattacharya A, Dong JQ, Fabian N, Haenlein M. 2021. Digital transformation: A multidisciplinary reflection and research agenda. J Bus Res. 122:889–901. ISSN 0148-2963. doi: 10.1016/j.jbusres.2019.09.022.
Vial G. 2019. Understanding digital transformation: A review and a research agenda. J Strategic Inf Syst. 28(2):118–144. doi: 10.1016/j.jsis.2019.01.003
Walker J, Pekmezovic A, Walker G, Walker J, Pekmezovic A, Walker G. 2019. Sustainable development goals: harnessing business to achieve the sDGs through finance, technology and law reform. John Wiley & Sons. doi: 10.1002/9781119541851.
World Economic Forum. The global risks report 2021, 16 Edition. http://wef.ch/risks2021
Zermeño G, Massive MG. 2020. Open online courses as a digital learning strategy of education for sustainable development. J Sustain Dev Energy Water Environ Syst. 8 (3):577–589. doi: 10.13044/j.sdewes.d7.0311.