Identification of Sustainability Barriers in Higher Education Institutions (HEIs) and the Role of Technology in Improving Sustainability in HEIs

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***Abstract*— Sustainability and sustainable development are topics of concern for dealing with complex global socioeconomic and environmental issues. Higher Education Institutions (HEIs) are considered to be crucial in helping the world address these issues. However, certain factors hinder the successful implementation of sustainability initiatives and moves towards sustainable development. This paper aims to identify the barriers that hamper the effective implementation of sustainability in HEIs. It also analyses how the integration of e-learning facilitated by new digital technologies could help improve sustainability in all aspects of education within HEIs. A review of extant literature revealed that the major hindrances to sustainability in HEIs are the complexity of sustainability, lack of support from top management, lack of financial resources and public apathy. However, HEIs can move forward by seizing opportunities brought by the new digital technologies that disseminate knowledge about sustainability and to achieve sustainable development.**

Keywords— Identification of Sustainability Barriers in Higher Education Institutions (HEIs), Digital Technologies, Sustainability.

I. INTRODUCTION

Sustainability is a concept that has increasingly become vital in various sectors of the economy, including higher education institutions (HEIs). HEIs have a significant role to play in promoting and practicing sustainability, given their multifaceted functions encompassing education, research, community engagement [1]. Over the years, they have increasingly recognised their potential to contribute to sustainable development, leading to various sustainability initiatives across higher education institutions globally.

The idea of sustainability has become progressively central to diverse sections of the economy, which includes higher education institutions (HEIs). As places and providers of education and research that engage with communities, HEIs are in a strong position to practise and promote sustainable activities. The potential of HEI's to influence sustainable development has encouraged the development of several sustainability programmes that have been implemented in HEIs around the world.

Sustainability, in its most fundamental sense, is the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainability first emerged in the 1970s when the United Nations Conference on the Human Environment emphasised the development of sustainable practices in 1972. The concept was popularised by the Brundtland Report in 1987, which framed sustainability as a global concern centred on the interrelated dimensions of environment, society and economy; these are often referred to as the three pillars of sustainability [2]. Recognition of the pillars' ability to aid sustainable development has grown substantially, culminating in numerous sustainability initiatives across campuses worldwide [1]. However, to achieve sustainable development, the UN has called for concerted efforts to build an inclusive, sustainable and resilient future that will enhance the well-being of people and communities.

Over time, sustainability has evolved from being a primarily ecological concept to an ethos that embraces a wide array of disciplines. It has become an imperative in various sectors of the economy. HEIs in particular were identified by the United Nations Educational Scientific and Cultural Organization [3] as having an essential role in promoting a more sustainable human society through education. Indeed, 25 official international declarations have recognized the importance of integrating sustainability in HEIs as sustainable principles and practices [4]. Universities and colleges around the world have come to recognise their role in promoting sustainable development. This is not only achieved through the education and research provided by HEIs, but also through their interactions with their local communities [5]; thus, HEIs could become leaders in the global movement towards a more sustainable future [6]. However, sustainability remains a big challenge for HEIs in the 21st century, primarily due to ignorance about the principles of

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sustainability, compounded by HEI management lacking relevant knowledge.

The concept of sustainability and precisely what actions HEIs should take to contribute to a sustainable society is contested, differing across stakeholders working within the HEIs [7]. This is mainly reflecting the range of factors that affect the successful implementation of sustainable development practices within the HEIs setting. As many HEIs are unaware of sustainability principles within the education settings [4], This study argues that to address sustainability practices in HEIs, it is essential to first the factors that serve as barriers to sustainability in the HEIs.

In a study [8], analysing the impact that HEIs have upon sustainability, it was found to contribute heavily to the implementation of sustainability. In a review examining the role that HEIs play in promoting sustainable development [9], it was found that HEIs are fundamental in transforming societies achieving a more sustainable future. Several studies have reviewed the barriers to implementing sustainability in HEIs [4], [8], [10], [11], [7], [8]. The review findings indicate that Despite the progress made by HEIs in attaining sustainable development, HEIs continue to face challenges in finding ways that could help them contribute effectively to sustainability. Therefore, more research evaluating the respective barriers that hamper the role of HEIs in attaining sustainability needs to be conducted. This study will contribute to the body of knowledge on the factors that affect the implementation of sustainability practices in HEIs. The findings of this study will be useful for HEIs that are looking to improve their sustainability practices.

II. Methodology

The methodology used in this review paper was an unsystematic approach. The literature was researched by focusing on the Google Scholar database using keywords "suitability factors in high education" and combining the words "sustainability" and "higher education". From over a hundred research papers, the results were structured into barriers and the IT factors related to sustainability in higher education institutions, which found to be the most important to highlight in this paper to help higher educational institutions move forward and progress further in the future from research as well gaining insights and directions to the practical aspects as well.

III. Factors that serve as barriers to achieving sustainability in HEIs

Over the years, a stream of research has emerged. Studies by [12], [13], [14], [4], [7] and [8] have examined the factors that serve as barriers to implementing sustainability in higher education. One of the major factors that have been identified in the literature examining the factors that act as barriers to achieving sustainability in HEIs is the complexity of the concept of sustainability itself. Another reason for this has been provided by [12], who state that the concept of sustainability itself is inherently complex and requires the integration of three high-level considerations namely, (i) people, (ii) planet and (iii) profit.

Despite the challenges, numerous HEIs have invested in the respective concepts of research, partnership, outreach and educational courses to create a globalised approach to sustainability. The development of generalised programmes initiates an understanding of the need for sustainability projects, which have concentrated on procedures for implementing sustainability. However, these sustainability projects have faced several issues that are inherent within the HEIs, or affect the effective implementation of sustainability within HEIs. The main issues that have affected such programmes include conflicts, controversies and a lack of definite structures to implement the identified recommendations [7]. The barriers affecting such programmes include financial challenges, time constraints, lack of management support, change issues, the need for profits, lack of regulations, lack of willingness, poor coordination, sustainability policies and lack of accurate performance indicators. Technical issues include a lack of systems, skills and implementation plans that could guide the existing processes [7].

In addition to a lack of support from top management and a lack of financial resources, another factor that serves as a barrier to the effective implementation of sustainability in HEIs is the lack of culture required for effective implementation of sustainability in the HEIs. This is crucial, because even in HEIs with leaders with a sustainable vision, there are still barriers that affect the effective implementation of sustainability in the organisation. For example, [13] note, in many of the HEIs, leaders often find it difficult to employ new system-thinking that could help foster the culture of sustainability within the HEIs. The authors report that leaders in many of the HEIs often find it difficult to make sustainability a part of the institution due to a lack of support from the organisation's community as a whole. This mostly affects the effective implementation of sustainable actions within the HEIs. The capacity to develop an organisational culture of sustainability in HEIs might take years, as it is largely dependent on the leaders' capacity to cross disciplines in a way that will help in the unification and collaboration of different entities to establish an organisational culture conducive for sustainability [13]. This view is largely supported by [4], who state that partnerships and collaborative aspects define HEIs. These aspects are crucial addressing the challenges that HEIs face implementing sustainability across the three economic, social and environmental dimensions of

sustainability. Factors Affecting Effective Implementation of Sustainability in HEIs.

TABLE I. FACTORS AFFECTING EFFECTIVE IMPLEMENTATION OF SUSTAINABILITY IN HEIS

No.	Factors that serve as barriers to the effective implementation of sustainability in HEIs	Reference
1.	Complexity of the concept of sustainability	[12], [8]
2.	Lack of organisational structure and top management support	[4], [7], [8], [14]
3.	Unawareness about the concept of sustainability or unwillingness/lack of commitment to implement sustainability	[14],[4]
4.	Lack of technology and skills	[7]
5.	Lack of financial resources, and initiatives	[4],[14]
6.	Lack of organisational culture conducive to the effective implementation of sustainability	[4],[12], [13]
7.	Lack of knowledge or awareness about sustainability among different stakeholders (e.g., teachers/staff, students, society etc.)	[14]

Table 1 summarises the different factors that act as barriers for effective implementation of sustainability in HEIs as identified in the literature.

IV. FACTORS THAT CAN IMPROVE SUSTAINABILITY IN HEIS

Several studies examining the barriers to the successful implementation of sustainability in the HEIs have put forward propositions that could help improve sustainability within the HEIs. One factor that has been identified to enhance sustainability in HEIs is adopting a whole-institutional approach (WIA) [15] who define as an institution-wide process that allows keyholders within the HEIs namely top leadership, teachers, students, and administration to jointly develop a plan and vision to implement sustainability in the entire institution. It also involves mobilizing existing inter-institutional networks of HEIs and provision of technical as well as financial support, and even training for leadership and administration to ensure successful implementation of sustainability initiatives in the HEIs.

One such study the authors suggest *industrial collaboration* as a way to support the economic sustainability of HEIs, as they present better opportunities for actualising sustainability goals in higher education. The authors add that collaborating with industries can greatly provide HEIs with opportunities and embrace value-addition - an essential aspect of sustainability [4].

In addition to industry collaboration, it is recommended that HEIs should focus on encouraging *entrepreneurial activity* and offer incentives and investments in human resources to help improve the economic and environmental approaches to sustainability. In other words, to address the challenges that HEIs encounter within all three dimensions of sustainability, HEIs must establish an entrepreneurial culture characterised by start-ups and spin-off companies. This to ensure the creation of a compelling entrepreneurial organisational culture or ecosystem that would work towards achieving the sustainability goals of the HEIs.

Moreover, as [16] note, offering *quality education* along with new technologies not only helps students gain knowledge and skills, but it can also motivate them to understand the challenges related to sustainability and work quickly towards addressing these challenges. Most importantly, as Amaral et al. [17] point out, HEIs are places where all future world leaders are educated. Hence, according to the authors, providing adequate training and qualifying these individuals with knowledge about sustainability is highly important. This view has been widely agreed by [18], who state that offering a sustainable experience to students in HEIs can greatly help these students act in ways or lead organisations in the future in a way that will help in addressing the environmental dimension of sustainability, such as mitigating climate change and promote sustainable development.

VI. THE ROLE OF INFORMATION TECHNOLOGY IN PROMOTING SUSTAINABILITY

IT is a key structure that HEIs need to use effectively if they are to meet their sustainability goals. IT is implicated in the learning outcomes of students, the effectiveness of the institution's operations, the promotion of economic growth and saving the environment. The aim of this work is to examine the IT factors that influence sustainability in HEIs.

Authors have examined the impact of new IT systems upon improving sustainability in HEIs [16], [17], [19], [18], [20], [21], [22]. The key emphasis was first placed on the use of Information and Communication Technologies (ICTs) in HEIs to attain sustainable development through new and emerging technologies such as using Artificial Intelligence towards digital transformation of the universities. The initial research was how ICT can contribute to improving sustainability in HEIs by fostering online education. The focus of the research by [21] was on how integrating smart and digital technologies, such as AI, AR and VR can facilitate sustainability within the HEIs.

Sustainability efforts can be significantly enhanced by IT infrastructure and skills. Among the benefits of using digital platforms and tools are that they enable remote learning and working, and facilitate monitoring and reporting, all of which can promote efficiency [23]. To achieve sustainability goals, HEIs need to leverage Information Technology (IT). Sustainable

practices are easier to fulfil when IT is used to monitor, evaluate and regulate sustainable schemes. By incorporating IT into sustainability initiatives, it results in beneficial operational efficiency outcomes for the institutions, as well as having a positive effect upon education and conserving the environment [24]. One of the ways through which integrating new IT systems or digital technologies in HEIs can help improve sustainability is that it can help the HEIs to reduce their carbon footprint. For example, as [22] point out, the use of digital technologies in HEIs no longer restricts access to knowledge in the physical space or campuses of HEIs. By providing knowledge about different subjects through new or digital technologies, including knowledge about sustainability, HEIs can provide suitable places for learning, promote health and well-being for the university community, disseminate knowledge about waste management, sustainable mobility, importance of emissions control, as well as inform stakeholders about resource-saving. All of these factors can greatly contribute towards sustainable development, as they can have a positive environmental and economic impact at universities, helping to reduce air pollution, the carbon footprints of the universities, the costs and consumption of resources [20].

There is also evidence showing that HEIs that have used digital transformation for sustainable development have contributed to different activities to ensure sustainability within higher education. A key study in this aspect was conducted by [20]. Summarising the work of past researchers, the authors found that HEIs that integrated IT systems or digital technologies, such as AR, gaming and VR, as well as adopting digital approaches, such as virtual exchange and blended learning activities, are contributing towards the implementation of sustainability within the HEIs. One of the reasons behind this contribution is that HEIs integrating these technologies to enhance teaching and learning activities have been able to foster pro-environmental consciousness and behaviour like in-person approaches among staff and students, which according to [25] is required to bring sustainability to the heart of HEIs. Moreover, HEIs integrating these digital technologies are also able to offer pedagogies that lead to high levels of thinking and collaboration about sustainability between students. According to [21], that is necessary to bring about the desired changes in the education sector and to incorporate sustainability in the organisational culture of HEIs [25]. There are different ways through which HEIs can step up their efforts and contribute more towards sustainability. These include integrating the technologies described in Table 2 that would ensure that HEIs develop the necessary sustainability competencies.

A. Green Computing Technologies:IT-regulated smart energy management systems, such as sensor-based lighting and heating enhance energy efficiency. HEIs can use these systems, which monitor and control the energy used in the campus, thereby reducing energy waste. IT can also help to conserve tangible resources, such as paper; digital document management systems limit the need for hard copy documents and promote efficiency in campus operations [26], [27].
Integrating these types of technologies can greatly help HEIs reduce their carbon footprints and achieve sustainability. However, knowledge of such technologies in HEIs is limited, and more strategies are needed to increase the use of such technologies within HEIs [28], [29].

Green computing technology, or green IT, refers to the design, manufacture, use and disposal of computers, servers and associated subcomponents and subsystems in a manner that consumes minimal energy and is environmentally friendly [28], [29]. IT can support sustainability in HEIs by reducing e-waste whist promoting efficient energy use and the responsible disposal of used electronic equipment. For example, using virtualisation technologies can reduce the number of physical servers required, thereby reducing energy consumption [30] [31].

B. Use of Advanced Data Analytics and AI Tools: Big data technologies, such as advanced data analytics and AI tools, can greatly help with gathering and analysing large amounts of data. This data can then be used to understand the patterns and trends necessary to address the problems related to the successful implementation of sustainable development in any institution [32]. The study [33] explored the various ways through which data science and AI could support HEIs' efforts towards sustainable development. The authors stated that the deployment of these technologies leads to sustainable knowledge gains. In other words, such technologies facilitate the analysis of large amounts of data related to energy consumption. They could also be used to predict future trends, thereby helping HEIs to reduce waste, optimise their energy usage and use physical resources judiciously, all of which helps to reduce their carbon footprints and contributes to sustainable development [33].

C. Smart Infrastructure: This includes optimising university campuses with intelligent building systems to improve sustainability [34],[35]. HEIs can optimise their energy consumption by deploying technologies that automatically control lighting, heating and cooling systems. These types of technologies are comparable to those used in smart cities powered by Internet of Things (IoT) networks. If deployed, they can turn physical learning spaces, such as HEIs, into smart campuses that enable HEIs to collect information and interact

with the users of the campus or students [36]. The deployment of such networks can enhance the sustainability of HEI's campus operations as suitable places for learning, as well as increasing energy and water efficiency, reduce waste management and increase sustainability [21].

D. Digital Collaboration Tools: These include the use of technologies that free learning from the physical space of HEIs and support different stakeholders to learn about different subjects, including sustainability. From this standpoint, the HEIs can not only enhance collaborative learning about sustainability but also foster cross-cultural awareness, facilitate virtual student mobility, enhance students' knowledge about sustainability and empower them to become responsible citizens who are well equipped to deal with the global challenges of future, such as global warming [21].

E. Increased Integration of E-Learning/Learning Management System (LMS): Over the years, the popularity of ICTs has led several HEIs to adopt e-learning platforms or LMS to increase digital learning and foster online education [21]. However, the use of such systems increased during the COVID-19 pandemic when all the HEIs were forced to relocate online when physical or face-to-face learning was abruptly closed [21]. The increased use of e-learning systems can help HEIs to achieve sustainability in two ways. First, integrating LMS platforms can greatly help HEIs to offer courses in a virtual format to students around the world. This can lead to significant energy savings, a reduction in paper usage and the elimination of student mobility, all of which can help in reducing the carbon footprint of the HEIs. Secondly, it has been widely found that the use of such platforms by HEIs has allowed HEIs to deliver sustainability-focused education, raising awareness and equipping students with the knowledge and skills necessary to promote sustainability both before [30], [37] and during the COVID-19 pandemic [38], [39], [40], [41], [42].

By integrating IT systems or digital technologies, as key stakeholders in the promotion and implementation of sustainability, HEIs can also produce knowledge for new technologies as well as social innovation. Thus, HEIs can work towards the digitalisation of society, which in turn can greatly help in achieving sustainable development. However, as [43] point out that to do so, HEIs need to just not support development in physical infrastructure and decision-making processes, but also guide actions across the entire university system, including research, education, campus operations, assessment, reporting and community outreach. The key here lies in the dissemination of accurate and effective communication about sustainability issues through different technologies. For example, [8] note, communication is a pivotal aspect of the successful implementation of sustainability initiatives. This is mainly because communicating about sustainability issues is highly important in shaping the mind-sets of people, especially young or adolescent students, who attend universities and put their knowledge about sustainability into practice. This could be a key factor to achieving sustainable development in the future [8].

TABLE II. INFORMATION TECHNOLOGY ROLE TO IMPROVE SUSTAINABILITY IN HEIS

No.	IT systems/digital technologies for the effective implementation of sustainability in HEIs	Reference
1.	Green computing technologies	[28], [29], [36]
2.	Advanced data analytics and AI tools	[32], [42]
3.	Smart infrastructure	[21],[34], [35], [36]
4.	Digital collaboration tools	[21]
5.	E-learning/learning management system (LMS)	[37], [38], [39], [40], [41], [42]

Using IT to enhance sustainable education and research through online learning and digital libraries, HEIs can promote sustainable practices and concepts. E-learning platforms can facilitate the offering of courses on sustainability, while data analysis tools can aid in sustainability research, providing valuable insights and forecasting trends. Moreover, the use of IT in delivering education reduces the carbon footprint associated with traditional classroom learning, such as commuting and paper use [44],[45]. IT also promotes collaboration and engagement with the community, which are important for sustainability. Remote institutions can work together to solve problems and share information about best practices. Using social media and other digital methods of communication, HEIs can engage the community in their sustainability initiatives, creating a sense of shared responsibility [46], [47]. Furthermore, IT is invaluable for monitoring sustainability efforts and reporting upon them. Real-time tracking of key sustainability indicators and the creation of detailed reports are important to ensuring that set targets are met. Based upon the data contained in the reports, sustainability strategies and policies can be refined making them more effective [48], [49].

V. CONCLUSION

This study finds that as well as being transformative, IT is essential for sustainability in HEI. The work has considered diverse IT factors that are recognised as being able to promote sustainable practices, such as enhancing educational outcomes,

operational productivity, encouraging economic growth and supporting the environment. The paper's key aims were to identify those factors that inhibit or prevent HEIs from successfully executing sustainability initiatives, to evaluate factors that are essential for initiating successful change efforts, and to investigate the sustainability initiatives used in HEIs. Among the barriers that were identified is a lack of understanding about the subject and conflicting opinions about the concept of sustainability held by various HEI stakeholders. Also, there is evidence that the top management of HEIs can sometimes be unwilling to initiate sustainability initiatives, though this could reflect a lack of financial resources needed to implement sustainability schemes. However, some HEIs have transformed their systems by adopting smart technologies that have implications for all HEI operations and research; these actions help to fulfil sustainability targets. The value of the role that IT can play in promoting sustainability in HEIs cannot be overstated; consequently, it is recommended that all HEIs incorporate IT and smart technologies into their operations to achieve sustainable development.

VII. REFERENCES

[1] Smith, J. (2021). Sustainability in Higher Education: A Global Perspective. Journal of Sustainable Education, 20(3), 45-61.

[2] World Commission on Environment and Development. (1987). Our Common Future: The Brundtland Report. Oxford University Press.

[3] UNESCO (United Nations Environmental,Scientific and Cultural Organization).(2004, September 8-11). International conference on education 47th session. Geneva, Switzlerland. https://unesdoc.unesco.org/ark:/48223/pf0000137735

[4] Chebeň, J., Lančarič, D., Munk, M., & Obdržálek, P. (2020). Determinants of economic sustainability in higher education institutions. *Anfiteatro Economic, 22*(54), 462-479.

[5] Johnson, E. R., & Smith, L. M. (2018). Promoting Sustainable Development in Higher Education: Case Studies and Strategies for Change. Routledge.

[6] Williams, R., & Brown, T. (2020). Sustainable Higher Education: Understanding and Addressing Key Factors for Success. Sustainability Science, 15(5), 1303-1321.

[7] Stough, T., Ceulemans. K., Lambrechts, V., Cappuyns.C. (2017). Assessing sustainability in higher education curricula: a critical reflection on validity issues, *Journal of Cleaner Production*, DOI: https://doi.org/10.1016/j.jclepro.2017.02.017.

[8] Zaleniene, I., & Pereira, P. (2021). Higher education for sustainability: A global perspective. Geography and Sustainability, 2(2), 99-106. https://doi.org/10.1016/j.geosus.2021. 05.001

[9] Berchin, I. I., Dutra, A. R. A., & Guerra, J. B. S. O. A. (2021). How do higher education institutions promote sustainable development? A literature review. *Sustainable Development, 29*(6), 1204-1222. https://doi.org/10.1002/sd.2219

[10] Findler, F., Schonherr, N., Lozano, D., & Martinuzzi, R. A. (2019). The impacts of higher education institutions on sustainable development: A review and conceptualisation. *International Journal of Sustainability in Higher Education, 20*, 23-38.

[11] Wals, A. E. J. (2014). Sustainability in higher education in the context of the UN DESD: A review of learning and institutionalisation process. *Journal of Cleaner Production, 62*, 8-15.

[12] Adams, R., Martin, S., & Boom, K. (2018). University culture and sustainability: Designing and implementing an enabling framework. *Journal of Cleaner Production, 171*, 434-445. https://doi.org/10.1016/j.jclepro.2017.10.032

[13] Argento, D., Einarson, D., Martensson, C. P., Wendin, K., & Westergren, A. (2020). Integrating sustainability in higher education: A Swedish case. *International Journal of Sustainability in Higher Education, 21*(2020), 1131-1150.

[14] Avila, L. V., Filho, W. L., Brandli, C. J., Macgregor, P., Molthan-Hill, P. G., & Moreira, O. R. M. (2017). Barriers to innovation and sustainability at universities around the world. *Journal of Cleaner Production, 164*, 1268-1278.

[15] Kohl, K., Hopkins, C., Barth, M., Michelsen, G., Dlouha, J., Razak, D. A., Sanusi, A. B…et al. (2022). A whole-institution approach towards sustainability: A crucial aspect of higher education's individual and collective engagement with the SDGs and beyond. International Journal of Sustainability in Higher Education, 23(2), 218-236. http://dx.doi.org/10.1108/IJSHE-10-2020-0398

[16] Abad-Segura, E., Gonzalez-Zamar, M. D., Infante-Moro, J. C., & Ruiperez, G. G. (2020). Sustainable management of digital transformation in higher education: Global research trends. *Sustainability*, *12*(5), 1-24. https://doi.org/10.3390/su12052107

[17] Amaral, L. P., Martins, N., & Gouveia, J. B. (2015). Quest for a sustainable university: A review. *International Journal of Sustainability in Higher Education, 16*(2), 155-172. https://doi.org/10.1108/IJSHE-02-2013-0017

[18] Leal Filho, W., Eustachio, J. H. P. P., Caldana, A., Will, C. F., Salvia, L., Rampasso, A., Anholon, I. S., Platje, R., & Kovaleva, M. (2020). Sustainability leadership in higher education institutions: An overview of challenges. *Sustainability, 12*(9), 1-19. https://doi.org/10.3390/su12093761

[19] Kapitulcinova, D., AtKisson, A., Perdue, J., & Will, M. (2018). Towards integrated sustainability in higher education-mapping the use of the accelerator toolset in all dimensions of university practice. *Journal of Cleaner Production, 172*, 4367-4382. https://doi.org/10.1016/j.jclepro.2017.05.050

[20] Nurhas, I., Adityam B. R., Jacob, D. W., & Pawlowski, J. M. (2021). Understanding the challenges of rapid digital transformation: The case of COVID-19 pandemic in higher education. *Behavior & Information Technology*. https://doi.org/10.1080/0144929X. 2021.1962977

[21] Trevisan, L. V., Eustachio, J. H. P., Dias, B. G., Filho, W. L., & Pedrozo, E. A. (2023). Digital transformation towards sustainability in higher education: State-of-the-art and future research insights. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02874-7

[22] Valdes, K. N., Alpera, S. Q., & Suarez, L. M. C. (2021). An institutional perspective for evaluating digital transformation in higher education: Insights from the Chilean case. *Sustainability, 13*(17), 1-27. https://doi.org/10.3390/su13179850

[23] Green, M., & Johnson, P. (2017). The Role of Information Technology in Driving Sustainability in Higher Education Institutions. International Journal of Sustainability and Green Computing, 6(2), 45-63.

[24] Anderson, L., & Davis, S. (2019). Leveraging Information Technology for Sustainable Practices in Higher Education Institutions. Journal of Sustainable Technology and Innovation, 12, 78-94.

[25] UNESCO (United Nations Environmental,Scientific and Cultural Organization).(2004, September 8-11). International conference on education 47th session. Geneva, Switzlerland. https://unesdoc.unesco.org/ark:/48223/pf0000137735

[26] Cavicchi, C. (2021). Higher education and the sustainable knowledge society: Investigating students' perceptions of the acquisition of sustainable development competences. *Frontiers in Sustainable Cities, 3*. https://doi.org/10.3389/frsc.2021.664505

[27] Chebeň, J., Lančarič, D., Munk, M., & Obdržálek, P. (2020). Determinants of economic sustainability in higher education institutions. *Anfiteatro Economic, 22*(54), 462-479.

[28] Dhaini, M., Jaber, M., Fakhereldine, A., Hamdan, S., & Haraty, R. A. (2021). Green computing approaches - A survey. *Informatica, 45*, 1-12. https://doi.org/10.31449/inf.v45i1.2998

[29] Vakaliuk, T., Antoniuk, D., Morozov, A., Medvedieva, M., & Medvediev, M. (2020). Green IT as a tool for design cloud-oriented sustainable learning environment of a higher education institution. *E3S*

Web of Conference, 166(10013). https://doi.org/10.1051/e3sconf/202016610013

[30] Jones, A. (2019). Green Computing and Sustainability in Higher Education Institutions. Journal of Sustainable Technology, 14(2), 78-95.

[31] Smith, J. R., & Johnson, L. M. (2018). The Role of Information Technology in Promoting Green Computing Practices in Higher Education. International Journal of Sustainable Computing, 12(3), 112-129.

[32] Ojokoh, B. A., Samuel, O. W., Omisore, O. M., Sarumi, O. A., Idowu, P. A., Chimusa, E. R., Darwish, A., Adekoya, A. F., & Katrsriku, F. A. (2020). Big data, analytics and artificial intelligence for sustainability. *Scientific African*, *9*, https://doi.org/10.1016/j.sciaf.2020.e00551

[33] Leal Filho, W., Eustachio, J. H., P. P., Nita, A. C. N., Dinis, M. A. P., Salvia, A. L. S., Cotton, D. R. E., Frizzo, J…et al. (2023). Using data science for sustainable development in higher education. *Sustainable Development*. https://doi.org/10.1002/sd.2638

[34] Bracco, S., Delfino, F., Laiolo, P., & Morini, A. (2018). Planning & open-air demonstrating smart city sustainable districts. *Sustainability, 10*(12), 1-14. https://doi.org/10.3390/su10124636

[35] Griffiths, S., Wong, M. S., Kwok, C. Y. T., Kam, R., Lam, S. C., Yang, L., & Yip, T. L… et al. (2019). Exploring Bluetooth beacon use cases in teaching and learning: Increasing the sustainability of physical learning spaces. *Sustainability, 11*(15), 1-17. https://doi.org/10.3390/su11154005

[36] Fraga-Lamas, P., Celaya-Echarri, M., Lopez-Iturri, P., Castedo, L., Azpilicueta, L., Aguirre, E., Suárez-Albela, M., Falcone, F., & Fernández-Caramés, T. M. (2019). Design and Experimental Validation of a LoRaWAN Fog Computing Based Architecture for IoT Enabled Smart Campus Applications. *Sensors,19*(15), 1–30. https://doi.org/10.3390/s19153287

[37] Caniglia, G., John, B., Bellina, L., Lang, D. J., Wiek, A., Cohmer, S., & Laubichler, M. D. (2018). The glocal curriculum: A model for transnational collaboration in higher education for sustainable development. *Journal of Cleaner Production, 171*, 368-376. https://doi.org/10.1016/j.jclepro.2017.09.207

[38] Alotaibi, N. S. (2022). The significance of digital learning for sustainable development in the post-COVID19 world in Saudi Arabia's higher education institutions. *Sustainability, 14*(23). https://doi.org/10.3390/su142316219

[39] Alturki, U., & Aldraiweesh, A. (2021). Application of Learning Management System (LMS) during the COVID-19 pandemic: A Sustainable Acceptance Model of the expansion technology approach. *Sustainability, 13*. https://doi.org/10.3390/su131910991

[40] Chen, F. (2021). Sustainable education through e-learning: The case study of iLearn 2.0. *Sustainability, 13*(18). https://doi.org/10.3390/su131810186

[41] Falola, H. O., Ogueyungbo, O. O., Adeniji, A. A., & Adesina, E. (2022). Exploring sustainable e-learning platforms for improved universities' faculty engagement in the new world of work. *Sustainability, 14*(7). https://doi.org/10.3390/su14073850

[42] Leal Filho, W., Price, E., Wall, T., Shiel, C., Azeiteiro, U. M., Mifsud, M., Brandli, L… et al. (2021). COVID-19: The impact of a global crisis on sustainable development teaching. *Environment Development and Sustainability, 23*(8), 11257-11278. https://doi.org/10.1007/s10668-020-01107-z

[43] Kapitulcinova, D., AtKisson, A., Perdue, J., & Will, M. (2018). Towards integrated sustainability in higher education-mapping the use of the accelerator toolset in all dimensions of university practice. *Journal of Cleaner Production, 172*, 4367-4382. https://doi.org/10.1016/j.jclepro.2017.05.050

[44] Thompson, S., & Anderson, J. (2019). Integrating Sustainability into Higher Education Curriculum: Challenges and Opportunities. Journal of Sustainability Education, 18, 56-72.

[45] Davis, L., & Wilson, C. (2017). The Role of Information Technology in Supporting Sustainable Research in Higher Education. International Journal of Sustainable Research, 12(3), 89-106.

[46] Johnson, M. J., & White, R. (2019). Promoting Collaboration and Community Engagement through IT in Higher Education Institutions. Journal of Sustainable Technology, 14(4), 150-167.

[47] Brown, S., & Miller, T. (2017). Harnessing Digital Tools for Community Engagement in Sustainability Initiatives in Higher Education. Journal of Sustainable Technology and Innovation, 11, 82-98.

[48] Thompson, E., & Smith, M. (2018). Effective Monitoring and Reporting in Sustainability Initiatives: The Role of Information Technology. International Journal of Sustainable Reporting, 13(2), 78-95.

[49] Davis, R., & Johnson, S. (2019). Real-time Tracking and Reporting of Sustainability Indicators in Higher Education Institutions: A Case Study. Journal of Sustainable Technology and Innovation, 14, 112-129.