The influence of using smart technologies for sustainable development in higher education institutions

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CHRONICLE	ABSTRACT
	Promoting sustainability development in education is a global endeavor, aiming to foster the sharing of experiences and knowledge on sustainability development. To achieve that, educational institutions worldwide have increasingly embraced educational technology and integrated online learning components into their instructional methods. This research focuses on the pivotal role of students as influential catalysts for advancing sustainable development within higher education. Specifically, it investigates the extent of students' familiarity with sustainable development initiatives within higher education institutions in the UAE. To achieve this objective, the study introduces the Technology-Integration Framework for Education Sustainable Development (TIFESD), which serves as an evaluative tool for appraising students' awareness of technology-driven elements woven into the broader context of Education for Sustainable Development (ESD) within their respective universities. The research employs a quantitative methodology, encompassing the collection of 513 survey responses from students across nine universities in the UAE. This data analysis explores the potential relationship between the integration of technology and students' cognizance of factors that bolster sustainable development. The study's outcomes underscore students' profound awareness of a spectrum of technology-driven elements, including Green Campus initiatives, Smart Education strategies, Smart Campus facilities, and the influence of curriculum and course offerings—all of which collectively contribute to the advancement of sustainable development practices within higher education institutions.

1. Introduction

Higher education institutions have increasingly acknowledged the significance of (ESD) in recent years while also recognizing the essential role of technology in advancing sustainable development (SD) (UNESCO, 2017; Tarrant et al., 2021) state that to achieve sustainable education, it is necessary to implement a sustainable development strategy that aims to foster policies and practices that are sustainable both on an individual and societal level. Sustainability is a vital strategic view for businesses; universities are no exemption (Zhao, et al., 2021). Wals (2014) mentions that some universities find sustainability as an additional way of profiling and organizing themselves. However, the sustainability of universities can be promoted by skilled persons such as researchers, students, and academics, who have been viewed as the key component of sustainable development strategies by institutions and nations (Wang & Hu, 2017; Hodges et al., 2020). ESD is an approach that promotes interdisciplinary learning, problem-solving, critical thinking, and active learning to address sustainability challenges at various levels

(UNESCO, 2021). Additionally, the report emphasizes the role of ESD in contributing to the achievement of the United Nations' Sustainable Development Goals (SDGs) and fostering a more equitable and sustainable future for all (UNESCO, 2017; UNESCO, 2021). However, students are powerful agents of change for sustainable development in higher education. UNESCO (2019); UNESCO (2021, 2023). The UNESCO reports admit that students play a vital role as change agents in promoting (ESD) and empowering them with the knowledge, skills, values, and attitudes needed to act as agents of change. According to João Marcelo Pereira Ribeiro et al., (2021), students are future leaders who will be expected to make decisions to achieve sustainability as they take up key roles in education in sustainable development. Furthermore, Heiskanen et al. (2016) argue that students should acquire the necessary skills and qualities to become agents of sustainability. Sterling (2010) agrees that students become catalysts for positive change by empowering students with knowledge, critical thinking skills, and a sense of responsibility towards the environment and society. Furthermore, students' engagement in sustainability-focused courses and research projects, recycling programs, energy conservation campaigns, and sustainable transportation efforts, develop a sense of responsibility, social and economic issues, and a deeper understanding of the environment (Leal Filho et al., 2019a). However, Leal Filho et al. (2019b) declare that one of the Barriers is the low levels of awareness among the stakeholders about sustainability development in higher educational institutions. Accordingly, González-Zamar, et al., (2020) state that the educational field seeks to increase knowledge about the link between information technologies and education for sustainable development, as suggested by UNESCO and the SDGs of the 2030 Agenda. However, limited studies have been conducted on the initiative to promote Education for Sustainable Development (ESD) in the Gulf Cooperation Council (GCC) countries, including the UAE, Saudi Arabia, Bahrain, Oman, Qatar, and Kuwait (Alotaibi, 2022; Alkhayyal, 2019; Mojilis, 2019; Alsaati et al., 2020; Heiskanen et al., 2016). However, MCKeown and Hopkins (2007) stress the need for significant efforts across all education system levels to ensure ESD's success. Consequently, researchers in the GCC countries highlight the importance of fostering sustainability awareness among students in higher education institutions, as they are powerful agents of change and play an essential role in achieving effective, sustainable development and building a sustainable future (Stephens et al., 2008).

To illustrate the limited studies in this area, Heiskanen et al. (2016) conducted a study in Bahrain, which revealed that students exhibited a lack of awareness regarding the sustainability initiatives implemented on their campus. Jiwane, (2013) states that education is essential to disseminating information about all dimensions of sustainability in Bahrain. In Saudi Arabia, Alotaibi (2022) emphasizes highlighting the role of higher educational institutions in sustainable development. However, Alsaati et al. (2020) noted a lack of sustainability awareness among students in Saudi universities. In Oman, Ambusaidi and Al Rabbani (2009) found that female university students developed a positive attitude toward reducing environmental issues and embracing ESD. Qatar has made significant progress in integrating ESD into its education system through national strategies and collaborations, benefiting from experiences in curriculum integration and fostering bilateral partnerships. In line with global trends, Higher Education Institutions in the UAE are gradually transitioning towards sustainability, although more research is needed in this context. The (UAE) began to invest in a smart learning program named Mohammed Bin Rashid Smart Learning Program (MBRSLP) in 2012, which aims to shape a new learning environment and culture in their national schools by launching smart classes. However, the UAE has recognized the importance of sustainability by designating 2023 as the "year of sustainability" and has implemented strategies to actively promote Education for Sustainable Development (ESD) and Sustainable Development (SD). Few Previous studies in the UAE have shown a positive attitude toward ESD among students, with the progress made in integrating sustainability into university curricula and research activities (Baroudi, 2023; Al-Naqbi & Alshannag, 2017). However, the literature review highlights a research gap in exploring students' awareness of sustainable development in higher education, particularly in the United Arab Emirates (UAE).

Despite some efforts, further work is required to promote sustainable practices within higher education institutions in the UAE. To address this research gap, the primary focus of this study will be to examine the level of students' awareness regarding technology-related factors that contribute to sustainable development in universities and colleges in the UAE. A practical framework will also be developed to assess students' awareness of technology integration factors associated with sustainable development in universities. Additionally, the study aims to answer the question: Are students aware of technology-integrated sustainability practices, initiatives, and efforts within their university toward sustainable development (SD)? The study will consider various technology-integrated factors such as Green Campus, Smart Education, Smart Campus, and Curriculum and Courses to assess students' awareness of sustainable development practices. The paper will be structured into sections that provide an overview of technology-integrated Education for Sustainable Development (ESD), present the proposed framework for exploring the students' awareness, outline the research methodology encompassing data collection and analysis, present the study's findings, offer conclusions, discuss implications, highlight limitations, and propose areas for future research.

2. A Technology-Integrated (ESD)

Technology has experienced rapid development and extraordinary growth (Almaiah et al., 2022a; Marei, 2022). According to Sadh (2019), Technology can help to spread awareness about Green and make it more feasible and accessible for everyone. Segalàs et al. (2010) state that students perceived sustainability as mainly related to technology. However, scholars have acknowledged the importance of technology in enhancing e-learning, supporting student engagement, collaboration among students and emerging technologies such as the IoT (Internet of Things) and AI (Artificial Intelligence) across various levels

and directions (Alrfai et al., 2023), and presents numerous applications that can be joined for success in education which leads to more effective and sustainable management of natural resources (Almaiah et al., 2022b; Leal Filho et al., 2023). As technological advancements unfold, the importance of strategically utilizing technology to promote sustainable development becomes increasingly evident (UNDP, 2020). Similarly, Silva-da-Nóbregaet al. (2022) state that higher education institutions create an ecosystem by ICTs to reach sustainability using a collaborative, governance-based, and adaptive learning-model to endorse better stakeholder liability Based on the goal of sustainability, Previous studies have identified factors contributing to technology-integrated Education for Sustainable Development (ESD), Silva-da-Nóbrega et al., 2022; Liao et al. (2022) propose various essential factors, namely smart campus infrastructure, smart education, IT green, and social engagement, which collectively address different aspects of sustainability. These components emphasize the role of technology in establishing eco-friendly campuses, implementing sustainable practices in educational processes, and encouraging active community participation.

3. Developing the Proposed Framework

Previous studies have significant practical growth in the field of Education for Sustainable Development (ESD) practice, making it a prominent topic in the agenda of numerous higher education institutions globally (Machado & Davim, 2023). Scholars such as Silva-da-Nóbrega et al. (2022) have proposed comprehensive frameworks that align dimensions with the Sustainable Development Goals (SDGs) and advocate for the integration of technology-driven initiatives, such as the Smart Campus Framework (SCF). This framework encompasses various components, including smart economy, smart education, smart environment, smart living, smart management, smart mobility, smart technology, and smart security. Dawodu et al. (2022) highlight the importance of contextual factors in implementing Campus Sustainability Assessment Tools (CSATs) and shaping sustainable campuses, emphasizing environmental, educational, and governance dimensions. Lim et al. (2022) classify ESD factors as commitment and awareness, assessment and critique, course coordination, structural transformation, and universities management, recognizing the active engagement of communities in advocating for sustainable development. Moreover, Zeeshan et al. (2022) proposed a Smart and Sustainable School framework comprising five key characteristics: Reliable and ICT infrastructure, emphasizing the need for secure, readily available, cost-effective, and environmentally friendly applications to achieve sustainability. Technology-driven smart classrooms to enhance learning experiences. Technology-enabled sustainable resource management for efficient utilization of resources. Smart school transport and in-campus security systems to ensure safety and convenience. Advanced pedagogies curriculum and interactive Learning Management Technologies to support innovative teaching methods. Moreover, the UN Environment Program (2021) introduced a framework that outlines a four-step process for universities to become sustainable. The framework provides valuable tips on quick wins and how to initiate this transformative journey.

This model aims to establish the essence of a sustainable university and charts a course towards achieving it. It also depicts the ways in which sustainability can progress in the four fundamental areas of a university: teaching & research, environment & climate, people & society, and governance & Administration. However, despite these progressions, there is a shortage of studies employing a conceptual framework that explores the technology integration factors contributing to sustainable development practice in the educational field (significant). The framework will answer the question What technology factors emphasize sustainability development in higher education? This study introduces the Technology-integrated Education for Sustainable Development (TIFESD) framework, encompassing technology-related factors like smart campus, smart education, green campus, and curriculum/course design as pillars of sustainable development in the context of technology. TIFESD offers a comprehensive approach to sustainable development, integrating technology factors that promote sustainability specifically within higher education institutions. These variables are Green Campus (Silva-da-Nóbrega et al., 2022; Sertyeşilışık, et al., 2018). Smart Campus (Polin et al., 2023; Liao et al. 2,022; Silva-da-Nóbrega et al., 2022) Curriculum and courses design (UNESCO. (2013, 2020), Smart Education (Silva-da-Nóbrega et al. 2022) and dependent variable Student awareness of ESD (Mojilis, 2019; Alsaati et al. 2020; Al-Naqbi, & Alshannag, 2017).

3.1 Green Campus

Previous research acknowledges the concept of a Green Campus as an innovative strategy that utilizes green technology and a green economy to address societal sustainability challenges (Sadh, 2019). This approach, called green ICT or green computing, involves applying environmental criteria and sustainability principles (Radu, 2016). Zeng et al. (2022) argue that the emergence of green technology innovation (GTI) offers a novel and impactful approach that prioritizes green environmental protection. Furthermore, Ulucak (2020) agrees that Green Technology has become one of the best alternative strategies for sustainable development. However, Green Technology is a term that encompasses various environmentally friendly practices such as energy efficiency, health and safety considerations, recycling, and the use of renewable resources. Organizations must adopt optimal resource utilization strategies in today's challenging and competitive business environment to ensure sustainable growth (Almaiah et al., 2022a). Higher education institutions can potentially foster connections between science, sustainability, and technology within their campuses (González-Zamar et al., 2020). Nada and Elgelany (2014) highlight that educational interventions play a crucial role in fostering attitudes and raising environmental awareness among students. However, it is crucial to implement a comprehensive green campus strategy that encompasses e-waste management, sustainable procurement, paperless strategies, and recycling. The presence of e-waste and its associated health risks pose a potential hindrance to achieving sustainable development goals. The Green Campus movement has gained significant momentum and is deemed

crucial for higher education institutions in delivering an optimal learning experience for college students. Recognizing the Green Campus as an integrated approach, Gandasari et al. (2020) emphasize its role within educational research and community service systems, with a strong focus on environmental management. Similarly, Leal Filho et al. (2019b) suggest that establishing green offices and similar governance structures support sustainable development efforts within higher education institutions. Therefore, it can be hypothesized that:

H$_1$: *The adoption of Green Campuses positively influences students' awareness of Education for Sustainable Development (ESD) in their universities.*

3.2 Smart Campus

Universities can enhance their services, streamline processes, and effectively work towards achieving sustainability goals. The concept of a smart campus is an emerging trend that holds the potential to revolutionize the education system. Smart campus initiatives, enabled by digital transformation in higher education, aim to create technologically advanced and sustainable educational environments to meet the evolving needs of students, faculty, and staff (Polin et al., 2023). A Smart Campuses initiates with pervasive, trusted wired, wireless connectivity outdoors and indoors (Valks, et al., 2021; Caţă, 2015; Adomßent et al., 2019). Alwaer et al. (2010) define Smart buildings as technologically aware, sustainable, healthy buildings that meet the needs of occupants and businesses, flexible and adaptable to deal with change. Furthermore, Martins et al., (2021) indicate that a Smart Campus fits into three conceptual categories: Smart Living, Smart Learning, and Smart Security and Safety. Liao et al. (2022) highlight the importance of sustainable design in campus buildings to reduce resource depletion and lower carbon to create a healthy environment for occupants. These initiatives involve implementing smart campus infrastructure, which includes technologies such as smart buildings, Internet of Things (IoT) devices, and sensors, to enhance energy efficiency, reduce carbon emissions, optimize resource utilization, and improve sustainability performance in higher education institutions (Martins et al., 2021; Abuarqoub et al., 2017). Moreover, integrating smart technology with the physical infrastructure on a smart campus can significantly enhance campus sustainability and improve decision-making outcomes. Automated systems in smart buildings can regulate temperature and lighting based on occupancy levels, leading to significant energy savings. Recognizing the role of universities in societal transformation, sustainability, and digital revolutions, universities are increasingly acknowledged as vital stakeholders in driving positive change (Silva-Da-Nóbrega et al., 2022). Based on the aforementioned context, the following hypothesis is developed

H$_2$: *Implementing Smart Campus positively students' awareness of ESD in their universities.*

3.3 Smart Education

While there is no consensus on the exact definition of smart learning, scholars unanimously recognize the positive influence of technology in facilitating smart learning and education. Integrating e-learning, IoT, virtual reality, gamification, augmented reality, and interactive multimedia has proven to enhance students' comprehension, engagement, critical thinking, and problem-solving abilities. Zeeshan et al. (2022) emphasize the transformative potential of the Internet of Things (IoT) in delivering sustainable, high-quality education and promoting equal learning opportunities. They highlight how IoT can address the challenges encountered by education providers and managers, ultimately fostering sustainability in education. Kim et al. (2011) mention the significance of cloud computing in creating smart learning environments. Additionally, Sood and Singh (2018) note the rising gamification trend in e-learning. Furthermore, Lampropoulos et al. (2023), and Terras et al. (2019) confirm the effectiveness of combining augmented reality with gamification elements and serious games, leading to appropriate challenge levels, increased engagement, and improved learning experiences for students. However, integrating smart education and modern information and communication technologies to enhance education quality aligns with sustainable development goals outlined by UNESCO (2015) and the United Nations (2005). Zhang et al. (2004) further support using multimedia-based e-learning systems, incorporating diverse media like text, images, sound, and video to present learning materials. The integration of technology in e-learning not only provides convenient access to educational resources and reduces travel requirements and carbon emissions while enhancing teaching and learning experiences. Colás-Bravo and Quintero-Rodríguez (2023) recognize YouTube's role in promoting sustainable education by overcoming barriers and catering to individual learner needs. Smart education contributes to Education for Sustainable Development (ESD) by fostering inclusive and equitable learning environments, personalized and flexible learning approaches, and the acquisition of 21st-century skills. Educational institutions can further enhance the effectiveness of ESD and support students' sustainable development knowledge and skills. Given these considerations, students need to recognize that their educational institutions integrate technologies into learning activities to achieve sustainable development goals. Hence, the following hypothesis is proposed.

H$_3$: *Integrating Smart Education effect positively affects students' awareness of ESD in their universities.*

3.4 Curriculum and courses Design

Incorporating technology into higher education curriculum and course design is crucial for advancing Education for Sustainable Development (ESD) goals and preparing students for a sustainable future (UNESCO, 2019). According to Osman et al. (2017), a sustainability-focused curriculum should offer students opportunities to holistically explore, analyze, and engage with the world, developing competencies necessary to tackle its complexity and achieve the agenda of vision 2030. However, higher education institutions should not only concentrate on campus greening but also implement pedagogic reforms within the context of ESD. Biancardi et al. (2023) highlighted the significance of introducing relevant tools in the course curriculum

to address economic opportunities, social inequalities, and environmental challenges in a sustainable energy system. Similarly, Msengi et al. (2019) stress the need for a curriculum that equips pupils to address and recognize sustainability challenges. Aligning assessment strategies with sustainability principles further enhances the integration of sustainability in syllabi. Furthermore, Hammer & Lewis (2023) propose that comprehensive empowerment should be included to address sustainable development challenges effectively. This empowerment can be achieved by emphasizing competency development throughout the program of study and enhancing educational elements, including learning outcomes, learning/teaching arrangement, and evaluations. However, Zeeger and Clark (2014) argue that a sustained impact on students' perceptions of sustainability is better achieved through its integration across the curriculum, rather than focusing on individual courses. Educators play a vital role in activating critical competencies within sustainability programs and course development, as Alkhayyal et al. (2019) emphasized. UNESCO (2017, 2013) recommends integrating sustainability principles and practices throughout all curricula, emphasizing critical thinking, problem-solving, and decision-making skills. To effectively integrate sustainability into educational programs, Tasdemir and Gazo (2020) highlight the importance of practical application within the curriculum. Universities should design their curriculum, practice, and courses to promote sustainability by incorporating interdisciplinary learning, experiential approaches, and specific tools and concepts (Barth et al., 2007; Franco et al., 2019). Various teaching approaches, such as social learning, gaming, case studies, problem-based learning, and project-based approaches, have proven successful in promoting ESD (Wals & Blewitt, 2010). Moreover, Kioupi and Voulvoulis (2022) stress the importance of aligning learning outcomes with sustainability and generating evidence of developing translated competencies in learners. Additionally, according to Ali et al., (2013), integrating environmental education into the curriculum heightens students' awareness of environmental issues and sustainability (Ali et al., 2013). This evidence will aid curriculum planners in creating appropriate programs. Lotz-Sisitka and Lupele (2015) affirm that incorporating sustainable practices into the curriculum enhances students' knowledge, skillfulness's, and attitudes. However, According to Winter and Cotton (2012), engaging in extracurricular projects and activities not explicitly integrated into the sustainable curriculum, like participating in faculties research, can enhance sustainable literacy and promote a culture change by fostering self-reflective abilities. In summary, integrating technology, interdisciplinary learning, experiential approaches, and sustainability-aligned assessment strategies into higher education curricula is essential for promoting ESD and empowering students to address sustainability challenges effectively. Therefore, the following hypothesis is proposed.

H4: Curriculum and courses Design impact positively students' awareness of ESD.
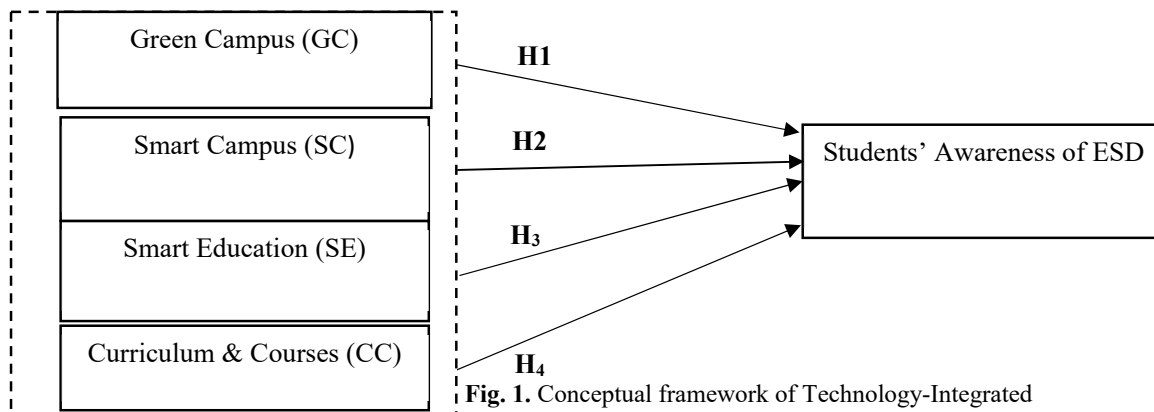

Fig. 1. Conceptual framework of Technology-Integrated

3.5 Students' Awareness and Knowledge

Empowering students and increasing their awareness and knowledge of sustainability are pivotal in fostering Education for Sustainable Development (ESD) and building a sustainable future (Wals & Blewitt, 2010; UNESCO, 2021; Tsaprouni & Papatheodorou, 2021). Higher education institutions are critical in empowering students as change agents for sustainable development and establishing a pervasive culture of sustainability on campus (Tsaprouni & Papatheodorou, 2021). To secure a more sustainable future, universities and policymakers should prioritize investments in sustainable education and awareness-raising initiatives (Tsaprouni & Papatheodorou, 2021). Integrating sustainability education into higher education enhances students' awareness, knowledge, and personal and professional development and equips them to become more actively engaged in sustainability (Mojilis, 2019). Furthermore, Alsaati et al. (2020) mention that sustainability awareness must be offered to learners through numerous channels, including university initiatives, governmental programs, and media. Moreover, as Barth et al. (2007) emphasized, educational institutions must foster interdisciplinarity and assist learners to take responsibility for their actions. However, Lozano (2006) acknowledges that the process of sustainability development within institutions is likely to encounter resistance from internal and external stakeholders. Corcoran & Wals (2004) ensure that introducing education for sustainability within the academy is not without its dilemmas. Sustainable universities ought to empower the younger generation by fostering student involvement in real-world projects and nurturing lasting, structured teachers-students' relations (Biancardi, et al., 2023). Higher education institutions must proactively foster students' awareness of sustainability practices and understanding related issues through diverse avenues, including curricula, co-curricular activities, and programs.

4. Methodology

This study proposes the factors related to technology-integrated education for sustainable development (ESD). It explores students' awareness of these factors in higher education institutions in the UAE, considering factors from previous studies such as Green Campus, Smart Campus, Smart Education, curriculum, and courses. The study employed a previously validated framework to conduct a quantitative descriptive-exploratory study using purposive sampling. Purposive sampling is a non-probability sampling method that involves selecting participants based on their relevance to the research objective. The study selects students from various nine universities located in Ajman, Sharjah, Dubai, and Abu Dhabi appropriate for the study. The survey included demographic questions and five sections. The questions were designed utilizing items from prior research to measure the constructs of the smart campus infrastructure (Silva-da-Nóbrega et al., 2022), Green Campus (Silva-da-Nóbrega et al., 2022; Sertyeşilışık, et al. 2018; Zeegers & Francis Clark, 2014) Smart Education (Silva-da-Nóbrega, et al. 2022; Junco, 2012) Curriculum and Courses and Students Awareness (Mahmud, 2017; AlNaqbi, & Alshannag, 2017; Zeeger & Clark, 2014).

4.1 Data Collection

The research was conducted across nine universities in the UAE, specifically in Abu-Dhabi, Dubai, Ajman, and Sharjah Emirates. A total of 513 surveys were collected from more than nine universities ln the UAE. These universities include Ajman University (AU), American University of Sharjah (AUS), United Arab Emirates University (UAEU), the University of Sharjah, Gulf Medical University, New York University Abu Dhabi, and Middlesex University Dubai, Arab Academy for Maritime Transport and Science Technology, and Heriot-Watt University. The participants were undergraduate and postgraduate students. Government and private universities are accredited by Ministry of Education (MoE) and align with the UAE's sustainability development (SD) strategy, which includes adopting Environmental, Social, and Economic Sustainability (ESD) principles. The universities should have national and international recognition and meet the standards set by MoE. Data collection took place in April 2023 using a hybrid method collect the data that involved an online survey administered through Google Forms and face-to-face interactions and social media (SM) platforms such as Instagram, Facebook, and WhatsApp's. The survey utilized a 5-point Likert scale, with respondents rating items on importance and performance. Demographic information, such as gender, majors, university campus, and academic year, was also collected.

5. Analysis of the data

5.1 Demographical Analysis

Table 1 presents the demographic analysis of this study participants and reveals key characteristics of the sample, including gender distribution, nationalities, academic year, universities attended, and colleges represented. Most respondents were female students, comprising 73.9% of the sample, while males represented 26.1%. Nationality: Most respondents had UAE nationality, accounting for 10.9% of the sample. Arab nationality was the most prevalent, with 52.6% of respondents. Asian nationality represented 17.0%, followed by European nationality (5.3%), African nationality (12.7%), and other nationalities (1.6%). Academic Year: Respondents were distributed across various academic years as follows: First Year (16.4%), Second Year (13.6%), Third Year (21.8%), Fourth Year (24.2%), Fifth Year (7.2%), Last Year (8.2%), and Postgraduate (8.6%). University: Most respondents were from Ajman University (70.0%). Other universities represented in the sample included the University of Sharjah (6.8%), Gulf Medical University (2.1%), American University of Sharjah (4.7%), New York University Abu Dhabi (2.9%), Middlesex University (3.1%), the Arab Academy for Science, Maritime Transport, and Technology (0.6%), Heriot-Watt University (2.3%), United Arab Emirates University (2.1%), and other universities (5.3%). The respondents' students were enrolled in various colleges: Business (32.0%), Engineering (11.7%), IT (6.6%), Medicine (9.6%), Law (4.5%), Dentistry (15.4%), Mass Communication (3.1%), Pharmacy (6.2%), Humanities and Sciences (4.7%), and Art & Design (6.2%).

Table 1

Demographic Characteristics Analysis

Attributes	Category	Frequency	Percentage
Gender	Male	134	26.1
	Female	379	73.9
Nationality	UAE Nationality	56	10.9
	Arab Nationality	270	52.6
	Asian Nationality	87	17.0
	European Nationality	27	5.3
	African Nationality	65	12.7
	American Nationality	8	1.6
University	Ajman University	359	70.0
	University of Sharjah (US)	35	6.8
	Gulf Medical University	11	2.1
	American University of Sharjah	24	4.7
	New York University Abu Dhabi	15	2.9
	Middlesex University	16	3.1
	Arab Academy for Science, Technology, and Maritime Transport	3	0.6
	Heriot-Watt University	12	2.3
	United Arab Emirates University	11	2.1
	Other universities	27	5.3

Table 1
Demographic Characteristics Analysis (Continued)

Attributes	Category	Frequency	Percentage
Colleges	Business	164	32.0
	Engineering	60	11.7
	IT	34	6.6
	Medicine	49	9.6
	Law	23	4.5
	Dentistry	79	15.4
	Mass Communication	16	3.1
	Pharmacy	32	6.2
	Humanities and Sciences	24	4.7
	Art & Design	32	6.2
Academic Year	First Year	84	16.4
	Second Year	70	13.6
	Third Year	112	21.8
	Fourth Year	124	24.2
	Fifth Year	37	7.2
	Last Year	42	8.2
	Postgraduate	44	8.6

5.2 Construct Validity

Table 2 presents the results of the construct validity analysis for five constructs: Green Campus (GC), Smart Campus (SC), Smart Education (SE), Curriculum and Courses (CC), and Student ESD Awareness (SEA). The table includes information such as outer loadings (λ), composite reliability (CR), average variance extracted (AVE), Cronbach's alpha α, and rho_A values for each construct. Specific values are provided for some items, while others are not specified. AVE values above 0.5 indicate acceptable variance captured by the construct. CR values above 0.7 indicate satisfactory internal consistency reliability. Similarly, Cronbach's α values above 0.7 suggest reliable internal consistency. Rho_A values serve as an alternative reliability measure comparable to Cronbach's α. The results demonstrate good construct validity for all constructs, with significant AVE, CR, Cronbach's α, and rho_A values at the $p<.001$ level, indicating the reliable measurement of each construct.

Table 2
Constructs Validity

Constructs	Items	λ	AVE	CR	Cronbach's α	rho_A
Green Campus (GC)	GC1	0.905	0.797	0.922	0.873	0.874
	GC2	0.88				
	GC3	0.844				
	GC1	0.706				
Smart Campus (SC)	SC1	0.813	0.558	0.863	0.801	0.802
	SC2	0.798				
	SC3	0.751				
	SC4	0.738				
Smart Education (SE)	SE1	0.887	0.722	0.912	0.872	0.875
	SE2	0.882				
	SE3	0.85				
	SE4	0.834				
Curriculum and Courses (CC)	CC1	0.89	0.764	0.907	0.846	0.847
	CC2	0.858				
	CC3	0.85				
	CC4	0.833				
Student ESD Awareness (SEA)	SEA1	0.871	0.796	0.921	0.872	0.873
	SEA2	0.826				
	SEA3	0.812				
	SEA4	0.732				

5.3 Discrimination Validity

To assess the discriminant validity. Hence, the study proposed using the Heterotrait–Monotriait ratio (HTMT) and Fornill–Larcker criterion as the dominant approaches for evaluating discriminant validity. (Almaiah et al., 2022c; Alrawad et al., 2023; Hair et al. 2017; Henseler, et al. 2015). Therefore, Table 3 presents the findings of the discriminant validity analysis using the Fornell-Larcker Criterion (1981) and the HTMT Ratios. The Fornell-Larcker Criterion assesses the distinctiveness of different constructs in the study, while the Heterotrait-Monotrait Ratio measures the correlation between constructs relative to their average correlations with themselves. According to the Fornell-Larcker Criterion, the square correlations between constructs should be smaller than the average variance extracted (AVE) for each construct. The table shows the square correlations and AVEs for Green Campus (GC), Smart Campus (SC), Smart Education (SE), Curriculum and Courses (CC), and Student ESD Awareness (SEA). Not all AVE values are specified in the table. Additionally, the Heterotrait-Monotrait Ratio

between pairs of constructs is provided. The Heterotrait-Monotrait Ratios for GC, SC, SE, CC, and SEA with other constructs are mentioned.

Table 3

Discriminant validity

Fornell-Larcker Criterion (1981)					
Green Campus (GC)	GC	SC	SE	CC	SEA
Smart Campus (SC)	**0.893ª**				
Smart Education (SE)	0.611	**0.747**			
Curriculum and Courses (CC)	0.458	0.454	**0.85**		
Student ESD Awareness (SEA)	0.63	0.685	0.46	**0.874**	
Heterotrait-Monotrait Ratio					
Green Campus (GC)					
Smart Campus (SC)	0.728				
Smart Education (SE)	0.523	0.546			
Curriculum and Courses (CC)	0.731	0.833	0.534		
Student ESD Awareness (SEA)	0.549	0.592	0.435	0.494	

Note: The bold values in the above matrix are the square correlations between the latent constructs and diagonals are AVE's. HTMT<0.850 (Kline, 2011)

5.4 Assessment of Structural Model

Table 4 presents the structural model assessment, focusing on the direct effects of independent variables (GC, SC, SE, CC) on the dependent variable (SEA). It includes parameters (β), standard errors (SE), t-values, 95% BCa-CIs (bias-corrected and accelerated confidence intervals), and remarks indicating hypothesis support. H1: GC → SEA shows a strong positive relationship (β =.670, SE = 0.030, t = 22.206, $p < 0.001$, 95% BCa-CIs: 0.605 to 0.725). H2: SC → SEA demonstrates a positive relationship (β =.123, SE = 0.045, t = 2.741, $p < 0.01$, 95% BCa-CIs: 0.042 to 0.218), albeit smaller than GC. H3: SE → SEA exhibits a strong positive relationship (β =.516, SE = 0.052, t = 9.872, $p < 0.001$, 95% BCa-CIs: 0.408 to 0.614). H4: CC → SEA shows a positive relationship (β =.443, SE = 0.056, t = 7.915, $p < 0.001$, 95% BCa-CIs: 0.330 to 0.546). All the hypotheses are supported, indicating significant direct effects of GC, SC, SE, and CC on SEA. These findings highlight the influence of these constructs in enhancing student awareness of ESD within the study's context.

Table 4

Structural model Assessment

Direct effects

Relationships	Beta	S.E	t-values	95% BCa-Cis	Results
H1) GC → SEA	0.67	0.03	22.206**	[0.605; 0.725]	Accepted
H2) SC → SEA	0.123	0.045	2.741*	[0.042; 0.218]	Accepted
H3) SE → SEA	0.516	0.052	9.872**	[0.408; 0.614]	Accepted
H4) CC → SEA	0.443	0.056	7.915**	[0.330; 0.546]	Accepted

*Note; *p < 0.01, **p < 0.001*

6. Discussion

Students are the powerful agents of change, for higher education sustainable development. Their awareness is essential to promote sustainability. This study explores students' awareness of sustainable development practices in the higher education institutions in the UAE. The study findings align with Koskela and Kärkkäinen (2021), who state that student learners play a significant role as change agents in the education for sustainable development. Mohammadi et al. (2023) corroborate the study finding that students' commitment to sustainability was positively influenced by their sustainability knowledge and attitudes, as well as the leadership and culture within the university. According to the study findings, students demonstrate a high level of awareness regarding their university's commitment to sustainable practices, including using curriculum promoting sustainability, implementing green campus initiatives, utilizing smart campus technologies, and integrating smart education methodologies. According to Sertyeşilışık et al. (2018) results, there is a need to enhance awareness about sustainability through education. Universities have a crucial role to play in tackling climate changes, particularly by offering courses on sustainability, promoting sustainable practices, and creating green campuses. This aligns with Ali et al. (2014) on students' awareness of the connection between technology use for learning, sustainability, and employability. Accordingly, João Marcelo Pereira Ribeiro et al., (2021) in Brazil agree that implementing sustainable development (SD) dissemination strategies in universities enhances students' understanding and awareness of SD significance. However, Mahmud (2017) in Malaysia states that a lack of awareness among the important stakeholders in curriculum development is a barrier to implementing ESD. However, the study results indicate that students recognize that curricula and courses in their universities are designed to support and advance sustainable development practices. These findings are in align with prior research conducted by Islam et al. (2021), who also observed that students fully understand sustainable development principles when technology is integrated into their educational experiences. Additionally, the findings support Al-Naqbi and Alshannag (2017) previous study confirming significant student awareness of ESD. However, the finding is inconsistent with Alsaati et al. (2020) study, which found in Saudi Arabia that students lack awareness regarding sustainability, particularly when recognizing renewable materials or recycling

materials that form a part of their daily routine. Unlike the findings of João Marcelo Pereira Ribeiro et al.'s (2021) study, which showed that students did not prominently perceive campus green infrastructure. Leal Filho et al. (2019a) also emphasized the significance of supporting campus sustainability initiatives and fostering awareness among learners and staff to promote SD.

Furthermore, the study's findings strengthen the understanding that students know the smart campuses' existence in their university to foster (ESD). This aligns with previous studies advocating adopting smart technologies and creating smart educational infrastructure, such as smart technologies in creating smarter educational environments, reducing energy, smart building management systems, creating smarter educational environments, and promoting sustainable campus practices. However, Silva-da-Nóbrega et al. (2022) point out, the importance of not relying solely on technology attributes in the smart campus process. Universities must align themselves with modern societies' present and future society needs and the social, and technological manner. However, the study indicates that students' awareness of the smart education method, such as e-learning, using IoT, virtual reality, gamification, and augmented reality adopted by their universities to promote sustainable educational practice, is consistent with Alotaibi, (2022), which emphasizes the potential of Saudi Arabia's higher education institutions in various aspects related to sustainable development, including their capacities for e-learning, improvisation, and organizations readiness. Furthermore, Cebrián et al. (2022) agree that Smart Classroom is well-suited for employing project-based and problem learning, cooperative inquiry and case study methods due to its technological advancements, environmental conditions, and processes. Zhang et al. (2004) emphasize that integrating digital technology into e-learning environments allows personalized learning experiences tailored to individual students' needs and preferences. Zeeshan et al. (2022) emphasize that IoT-based smart learning contributes to Customized learning environments, and online or distance learning can be improved effectively by IoT. Moreover, the study indicates that students are highly aware of promoting sustainable development within their curriculum this finding is consistent with previous studies emphasize that when students are made aware of sustainability issues through their curriculum, they become more conscious of their impact on the environment and are motivated to adopt sustainable practices. Furthermore, the work indicates that learners are highly aware of promoting sustainable development within their curriculum this finding is consistent with Yuan, et al. (2021) mentioned that to enhance the implementation of ESD, a comprehensive approach that includes both formal and non-formal education, along with curriculum integration, is essential. This approach raises competencies, knowledge, and students' awareness related to sustainability and promotes their active engagement in sustainable practices. The results further support the notion that students are actively engaged and informed about the importance of sustainability within their curriculum and coursework to enhance learners' overall commitment and academic accomplishment (Tarrant et al., 2021). Likewise, in Korea, Gress and Shin (2017) recognize the necessity of systemic transformations in current educational practices to effectively incorporate sustainable principles and methods into technical curricula when implementing green curricula. Nevertheless, the study is consistent with earlier works stating that incorporate sustainability into Business schools curricula, teaching, research, and operational practices, enhances students' understanding and motivation to address sustainability challenges (Painter-Morland et al., 2016).

7. Research Implications

Despite utilizing empirical findings from the UAE, the central issue addressed in this study possesses universal significance across diverse higher education systems in our interconnected world. Consequently, scholars from other countries, particularly those in developing nations, may find it valuable to investigate the applicability of the predictors identified in this work. This work contributes to the comprehension of the significance of technology in advancing Education for Sustainable Development (ESD) within a Gulf country. It provides valuable insights for further implementing technology-driven sustainability initiatives in higher education. A theoretical framework contains potential starting points for subsequent ESD research. the Technology-Integrated Framework of Education Sustainable Development (TIFESD), is introduced, underlining technology's role in enhancing ESD. The TIFESD framework incorporates four key factors: Green Campus, smart Education, and curriculum and Course Design, integrating technology into the sustainable practices of higher education institutions, recognizing its potential to revolutionize and amplify sustainability efforts. Applying TIFESD to educational settings, offer new avenues for transformative and impactful sustainability practices to emerge within higher education. The framework expands understanding of the association between technology and sustainability and provides practical guidelines to maximize the potential of technology in promoting sustainable development within educational environments. This study presents an extensive and inclusive framework that promotes technology's effective integration and utilization to advance sustainable development goals in higher education. Its implementation holds the potential to revolutionize sustainability practices, foster innovation, and contribute to the realization of a more sustainable future through education. The study practically validates the framework by examining how these factors influence the awareness levels of students from different cultures, genders, majors, and academic years.

8. Limitations and Future Research

The study acknowledges certain limitations. Firstly, the study model is restricted to factors that serve as tools for exploring technology-integrated educational sustainable development. Additional variables may be included in future studies to align with researchers' objectives in ESD. Moreover, as our research findings are derived from a single country, the UAE experiences, yet will still provide significant inputs and benefits to a global society and discussions about ESD's future worldwide.

Additionally, this study has shed light on the relevance of ESD practice in one of the Gulf countries. However, future studies can clarify further by examining a broader range of locations. Another limitation pertains to the nature of the data collected. The work relied on an online and face-to-face written voluntary orientation task, which may not ensure that all students were fully engaged and responded accurately to the questions.

9. Conclusion

  Promoting sustainability development in education is a global endeavor, aiming to foster the sharing of experiences and knowledge on sustainability development from various regions and countries worldwide. This collective sharing of insights has the potential to expedite the advancement of sustainability initiatives and the achievement of Sustainable Development (SD) goals. The study focused on students' awareness of technology-integrated factors that support SD significance, and sustainable development practices in universities. The findings suggest that there are no barriers in universities regarding students' awareness of the effective integration of technology in sustainability development practices. Furthermore, the study results confirm the extent of students' awareness of sustainability development concerning technology. However, universities should also emphasize promoting sustainability through other factors in education. The study yielded two significant findings. Firstly, the study results provide empirical evidence for ESD practice and the students' awareness as they can actively contribute to creating sustainable communities and tackling change challenges. Secondly, the study presented the Technology-Integrated Framework of Educational Sustainable Development (TIFESD). This conceptual framework explores the influence of technology integration factors, such as green campus, smart campus, smart education, and curriculum and course design, on students' awareness of Education for Sustainable Development (ESD). This framework provides valuable insights into the role of technology in promoting ESD and establishes a solid foundation for integrating technology into sustainability practices within higher education institutions.

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