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Sustainable Technological Practices in Educational Settings: An Assessment of Lebanese Students' Intention to Adopt Sustainable Behaviour

Basma Bchennaty[1]*, Mazen Massoud[2], Abir El Fawal[3], Muhammad Nauman Khan[4]

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ABSTRACT

Purpose: Lebanese universities encounter pedagogical and didactic challenges in the integration of sustainable practices and technologies due to a predominantly theoretical curriculum that lacks practical application. Consequently, this study seeks to assess the impact of sustainable technologies on students' adoption of sustainable behaviours. **Method:** This descriptive quantitative study employs a hypothetico-deductive approach. Data were collected through a questionnaire distributed to students at two university campuses in northern Lebanon, resulting in 310 valid responses obtained via convenience sampling. The exploratory factor analysis was conducted using the principal component analysis method, while confirmatory factor analysis was utilized to test the research hypotheses. **Findings:** The findings indicate that the integration of sustainable energy sources and green technological practices within Lebanese universities significantly enhances students' intentions to adopt sustainable behaviours, with an observed increase of 51%. Universities are actively promoting practices such as composting and recycling, encouraging students to replicate these responsible behaviours in their daily lives. Education for sustainable development focuses on real-world applications and fosters student initiative in engaging with sustainability practices. **Implications for Research and Practice:** Sustainability technologies and their applications have been enhanced through ongoing theoretical contributions and evolving social practices. Future research should investigate how specific features of sustainability programs affect the variability in students' behaviours.

Introduction

Sustainability topics such as pollution, climate change, and the significant loss of biodiversity are now ingrained in contemporary curricula (Tonietto et al., 2021; Zahra & Mifsud, 2021). The concept of sustainable development has rapidly gained traction,

[1] Faculty of Business Studies, Arab Open University (AOU), Saudi Arabia.
ORCID iD: https://orcid.org/0009-0003-1332-6931, Email: b.bchennaty@arabou.edu.sa
[2] Faculty of Business Administration, Jinan University (JUT), Lebanon.
Email: mazen.massoud@jinan.edu.lb
[3] Faculty of Business Administration, Beirut Arab University (BAU), Lebanon.
Email: a.fawwal@bau.edu.lb
[4] Faculty of Business Studies, Arab Open University (AOU), Saudi Arabia.
Email: m.nauman@arabou.edu.sa
*Correspondence: b.bchennaty@arabou.edu.sa

becoming a focal point for media, businesses, and political agendas. As a comprehensive principle, sustainability addresses environmental, societal, economic, and political dimensions, as well as community challenges. However, its associated concepts—such as environment, energy, and biodiversity—have become commonplace in social discourse, raising critical societal questions. Within this context, Education for Sustainable Development (ESD) is integrated across all levels of schooling, even though it does not constitute a distinct school subject (Nugroho, Juwita, & Febrianti, 2022). ESD is recognized as a key mission within the Education Code, integrating school programs and educational projects that engage students. There is a critical need to enhance the education of younger generations in this domain (Sever & Tok, 2022). ESD serves as a crucial tool for cultivating future ecologically responsible citizens by fostering critical thinking and knowledge, thereby equipping them to actively participate in societal activities and debates (Tharakan, 2023).

Sustainable development topics are embedded within all qualifications in both technological and vocational education pathways. Despite the extensive availability of teaching resources and comprehensive curricula, educators face significant pedagogical and didactic challenges in aligning with official guidelines on the implementation of sustainable practices and technologies. This is largely due to the theoretical nature of education, which often relies on implicit curriculum content that lacks practical applicability (Fekih Zguir, Dubis, & Koç, 2022). Academic institutions play a pivotal role in promoting sustainable technologies by drawing on their existing foundations in ESD (Cebrián, Junyent, & Mulà, 2020; Rauch, Steiner, & Kurz, 2022). Universities play a pivotal role in influencing students' behaviours by shaping their mindsets and technical skills, contributing to the advancement of technology through knowledge production, workforce training, and the creation of sustainable enterprises (Al-Naqbi & Alshannag, 2018; Pouratashi & Zamani, 2022). This study focuses on examining the implementation of sustainable technologies within Lebanese universities as educational environments. The central question addressed is: How do the application of sustainable technologies affect students' intentions to adopt sustainable behaviours in Lebanese universities?

This study aims to assess the impact of sustainable technologies on the behavioural changes of students, specifically evaluating the influence of these technologies on Lebanese students' intentions to adopt sustainable behaviours, with a focus on technical solutions rather than teaching practices. Drawing on the analyses of Ferrer-Balas, Buckland and de Mingo (2009), Borg and Vinterek (2020), and Antonaras, Iacovidou and Dekoulou (2018), the implementation of sustainable technologies necessitates modifications in campus design and layout to align with the expectations of key stakeholders, including students, educators, parents, and staff. Sustainability involves transforming traditional educational environments into sustainable, healthy, and safe spaces for learning and teaching. Educational institutions play a crucial role in facilitating the ecological transition and enhancing the well-being of all community members (Al-Nuaimi & Al-Ghamdi, 2022; Demaidi & Al-Sahili, 2021). When the current generation receives appropriate education on sustainable technologies, they acquire practical skills for implementing complex technological practices. Education provides them with the necessary tools and reflective frameworks to navigate the complexities of sustainability issues within their communities, enabling them to develop solutions tailored to local contexts while considering global

implications, such as reducing local pollution (Albert & Uhlig, 2022; Toledano, Gessa, & Sanchez-Herrera, 2022). Education acts as a catalyst for behavioural change, guiding students through a systematic analysis process applicable to various sustainability challenges, including environmental, societal, and economic issues (Torroba Diaz et al., 2023; Weber et al., 2023).

This research is structured into five sections. Following the introduction, the second section provides an overview of existing literature on sustainable technologies and practices in universities and outlines the conceptual framework based on recent debates derived from the hypotheses. The third section details the research methodology. The fourth section presents an empirical analysis of two sustainable technology policy measures recently implemented at two Lebanese universities. This empirical analysis evaluates the impact of sustainable practices, including sustainable learning methods, sustainable energy sources, recycling, and the development of green buildings and campuses. The final section emphasizes the need for universities to implement dynamic and sustainable strategies and promote them on both national and global levels. Furthermore, universities and political leaders should adopt coherent strategies, actionable measures, and indicators that are tailored to the needs of stakeholders.

Literature Review

Universities extend their role beyond mere education and knowledge transmission by engaging with their economic and social environments and fostering societal changes through the integration of sustainable practices within their educational settings (Pan et al., 2018; Torroba Diaz et al., 2023). This engagement presents universities with a significant challenge of transformation. By addressing this challenge, higher education institutions contribute to broader economic and social development, embodying the principles of University Social Responsibility (USR) (Comoli et al., 2021). The USR approach underscores the university's pivotal educational role in safeguarding the needs and interests of future generations (Widianingsih, Triyuwono, & Djamhuri, 2022). According to international standards, USR emphasizes placing sustainable development and social responsibility at the core of universities' development strategies to establish sustainable technological practices within educational environments (Bakirova et al., 2022; Elrayah & Piaralal, 2023; Leko Šimić, Sharma, & Kadlec, 2022; Rababah et al., 2021).

Higher education institutions have recognized their societal responsibilities, and leading universities have begun implementing sustainable technological practices on their campuses (Anthony Jnr, 2021; Fadeeva & Cherkasova, 2021). The application of a sustainable development approach on campus differs from the implementation of specific projects within organizations. Sustainable technological practices primarily address environmental concerns, reflecting a holistic vision and long-term transformative potential for universities (Pena-Cerezo, Artaraz-Minon, & Tejedor-Nunez, 2019). Universities play a critical role in educating future leaders and shaping societal attitudes, thereby contributing to the development of tomorrow's society (Deroncele-Acosta, Palacios-Núñez, & Toribio-López, 2023). Higher education institutions are incorporating sustainability into their curricula and programs, committed to guiding students in sustainable development (Dziubaniuk, Ivanova-Gongne, & Nyholm, 2023). This approach to sustainable development begins with initiatives such as recycling or establishing bicycle parking

spaces and extends to a comprehensive re-evaluation of existing practices and the creation of new concepts based on innovative principles (Demaidi & Al-Sahili, 2021; Weber et al., 2023). Consequently, universities are fostering stakeholder participation in decision-making processes. Sustainable education in universities is essential for enhancing awareness of ecological and ethical issues, and for developing values, attitudes, skills, and behaviours that align with sustainable development goals, in accordance with international organizational standards such as those set by UNESCO.

UNESCO's Decade of Education for Sustainable Development Implementation Plan outlines five key goals: enhancing the role of education for sustainable development, facilitating stakeholder networking, promoting diverse learning and public awareness, improving teaching quality in sustainable development, and developing capacity-building strategies at all educational levels (Brunold & Ohlmeier, 2022; Diemer, Khushik, & Ndiaye, 2020; UNESCO, 2017). The plan focuses on themes such as environmental protection, natural resource management, biodiversity, corporate responsibility, and citizenship. It aims to integrate sustainable education across all levels of learning to drive societal change, with the younger generation as a key driver for future societal transformation (Beisembayeva & Issina, 2022; Martínez et al., 2021). Consequently, sustainability is becoming increasingly important in organizations, with managers and employers expecting graduates to possess knowledge and skills in sustainability to enhance industry performance (Dziubaniuk et al., 2023; Ofor-Douglas, 2023). Research on students' attitudes and skills regarding sustainable technological practices indicates that a significant majority view sustainability as a critical component of their university experience. They believe that their institutions should support them in acquiring relevant knowledge and enhancing their intention to adopt sustainable behaviours.

Sustainable Technological Practices

While initiatives in sustainable technological practices hold promise, current educational fields exhibit considerable variability in the application of these technologies on campuses. The strategies employed do not always align with the principles of sustainable development (Albert & Uhlig, 2022; Das, Lim, & Aravind, 2022). Nevertheless, research by Albert and Uhlig (2022) and Ferguson et al. (2022) confirms that even minimal integration of sustainable technologies in education can influence students to adopt sustainable practices in their personal lives and future careers. Dinglasan, Luyon and Abiog II (2021) and Homer and Khor (2022) highlight the pivotal role and responsibility of students in implementing sustainable technologies. This evolving role challenges traditional teaching methods that focus on practical instruction. Education must embrace sustainable topics through innovative learning approaches that emphasize problem-solving and knowledge sharing, fostering the dissemination of adaptable content (Alshamsi & Ogdol, 2022; Ariefahnoor & Nugroho, 2022; Kirchhoff & Keller, 2021; Singh, Bhatt, & Singh, 2021).

Sustainable education fosters the development of social skills by shifting from traditional educational approaches, which often operate in isolation from knowledge development, to practical teaching and learning that emphasizes direct communication with students (Gorina et al., 2023; Pilotti & Al Ghazo, 2020). This approach aligns with the vision of sustainable development by focusing on environmental issues and positioning

students as active, responsible citizens. Education for sustainable development employs diverse pedagogical methods that emphasize real-world situations, thereby enhancing students' sensitivity, initiative, creativity, and sense of responsibility (Zhao & Cheah, 2023). In this context, the learning ecosystem encompasses the university's infrastructure—such as stakeholders, systems, tools, and technologies—that supports the educational process. Sustainable practices, including sustainable learning methods, energy sources, recycling, and the development of green buildings and campuses, facilitate education and promote behavioural change (Akhtar et al., 2022; Ferguson et al., 2022).

Sustainable Technological Practices and Students' Sustainable Behaviour

The acquisition of knowledge regarding sustainable technology is complemented by practical experiences designed to enhance social and personal skills. Sustainable practices, such as paper recycling within active learning strategies, facilitate shifts in attitudes, behaviours, and values toward adopting sustainable practices. Students exposed to sustainable technologies on campus can access comprehensive information on related topics through dedicated websites. Drahein, De Lima and Da Costa (2019), Gomez and Yin (2019), and Dziubaniuk et al. (2023) assert that the promotion of green practices on campus increases awareness of sustainable technologies and encourages changes in future behaviour. Gorina et al. (2023), Pilotti and Al Ghazo (2020), and Zhao and Cheah (2023) have identified that integrating sustainable development lessons into curricula is crucial for enhancing students' awareness of sustainable technological practices, particularly in environmental contexts. In this regard, Nouri et al. (2023), Adeniran, Nubi and Adelopo (2017), and Rauch et al. (2022) have explored aspects such as resource conservation, waste management, biodiversity, and climate change mitigation.

There is growing interest in the connection between students' intentions to adopt sustainable behaviours and the sustainable technological practices implemented by universities. Nugroho et al. (2022), Tharakan (2023), Borg and Vinterek (2020), and Albert and Uhlig (2022) highlight the essential role of university education in fostering sustainability and its beneficial impact on both current and future student behaviours. Universities that integrate greener practices into their academic curricula and student accommodations tend to experience higher student retention rates. These institutions are often referred to as "living labs" for sustainability, where collaboration among students and university leadership at all levels fosters sustainable behaviours (Fanea-Ivanovici & Baber, 2022; Hernández-Diaz et al., 2021). Furthermore, research indicates that e-learning and programs focused on pro-environmental and sustainable consumption have a significant influence on students' intentions to adopt sustainable practices. Such programs not only support institutional sustainability goals but are also crucial for advancing sustainable higher education (Adams, Martin, & Boom, 2018; Davey, 2017; Duram & Williams, 2015).

Therefore, universities that adopt sustainable technological practices, including e-learning and the promotion of sustainable behaviours, significantly impact students' attitudes and behaviours towards sustainability. In summary, the implementation of sustainable technological practices and university initiatives on campus substantially affects students' intentions to engage in sustainable behaviours. Consequently, the first hypothesis is proposed.

H1: *Sustainable technologies influence students' intention to adopt sustainable behaviour.*

Sustainable Learning Methods

Universities are increasingly adopting sustainable learning methods, which are supported by sustainable teaching practices. These methods prioritize the development of cross-disciplinary skills and autonomy alongside the acquisition of disciplinary knowledge, leading instructors to emphasize the process of learning rather than just content (Holloway & Mengersen, 2018; Trang, 2021). Educators advocate for the use of technology, such as tablets and computers, to minimize paper usage in the classroom. The availability of online resources has enhanced students' ability to conduct research and attain their degrees. Technology use in education equips students with the technical skills needed to address practical challenges in their professional lives. The primary advantage of sustainable learning methods is their ability to facilitate and enhance the learning experience. Both instructors and students integrate sustainability principles into everyday practices through sustainable learning environments such as eco-schools or green campuses (Pardal, Romeira, & Durão, 2020).

Nölting et al. (2020), Sun and Zhang (2022), and Mohammadi et al. (2023) found that sustainable teaching practices positively impact students' intentions to adopt sustainable behaviours. Sonetti, Lombardi and Chelleri (2016) and Ferreira et al. (2021) observed that using sustainable materials, like smart tabs instead of paper, stimulates students' interest and enhances their sustainable knowledge. Additionally, Nölting et al. (2020), Sun and Zhang (2022), Drahein et al. (2019), and Gomez and Yin (2019) highlighted that universities fostering sustainable campuses through such practices encourage students to adopt sustainable behaviours. By integrating sustainable teaching methods into curricula and promoting environmental responsibility, universities can significantly influence students' commitment to sustainability. Thus, the second hypothesis is proposed based on these findings (Bali et al., 2023; Holloway & Mengersen, 2018; Trang, 2021).
H2: *Sustainable learning methods influence students' intention to adopt sustainable behaviour.*

Sustainable Energy Sources

Universities are increasingly prioritizing renewable energy as they strive towards a carbon-neutral future (Tian et al., 2022). Commonly utilized renewable energy sources on campuses include solar, wind, and biogas, all of which offer substantial environmental benefits due to their minimal waste and low pollutant emissions. These energy sources, derived from the sun, wind, and water, are considered virtually limitless and contribute positively to the local economy, social infrastructure, and environmental health (Getu & Attia, 2016). Institutions invest in on-campus renewable energy systems, such as solar panels and wind turbines, to provide a reliable and sustainable energy supply. These technologies not only support educational activities but also ensure the long-term sustainability of educational institutions (Ayuningtyas & Adianti, 2022).

Education in sustainable energy equips students with practical skills applicable in their future careers. According to Getu and Attia (2016) and Ayuningtyas and Adianti (2022), integrating courses that provide skills pertinent to the energy sector fosters the adoption of sustainable practices. Such educational programs effectively highlight the benefits of sustainable energy sources, enhance students' awareness of sustainability, and influence their behaviour. While personal incentives motivate students, the combination of personal

and societal benefits significantly boosts their intention to embrace sustainable practices (Abdallah et al., 2022; Agovino, Matricano, & Garofalo, 2020). Knowledge and skills related to sustainable energy represent an initial step in cultivating energy awareness, with students drawing inspiration from their education to advance their sustainable adoption processes (Akinwale, 2022; Karatepe et al., 2012). Pastor et al. (2020), Montoya and Perea-Moreno (2020), and Leal Filho et al. (2019) assert that students' intentions and decisions to adopt sustainable behaviour are positively correlated with the knowledge they acquire. Sustainable energy sources motivate students within social contexts and enhance energy education programs. Project-based learning in energy, where students identify problems, develop solutions, and explore answers, proves effective in promoting sustainable behaviour. Hence, the third hypothesis is derived from the research of Tian et al. (2022) and Getu and Attia (2016).

H3: *Sustainable energy sources influence students' intention to adopt sustainable behaviour.*

Recycling

Recycling involves repurposing materials to create new products, a practice crucial for promoting environmental sustainability by reducing the need for new resources (Agovino et al., 2020; Kılkış et al., 2019). This process not only conserves resources but also engages students in hands-on activities, as they generally appreciate practical, manual tasks. University waste, primarily consisting of paper, is categorized as domestic waste and requires dedicated recycling bins in classrooms and offices (Singhal et al., 2019). Therefore, the fourth hypothesis is formulated based on these findings (Agovino et al., 2020; Kılkış et al., 2019). Universities increasingly adopt sustainable and eco-friendly products, such as those that are recyclable, biodegradable, or have a low carbon footprint. These products benefit both the environment and the universities' budgets. Research by Singhal et al. (2019) and Akindeji, Tiako and Davidson (2019) explores how university recycling policies influence students' intentions to engage in sustainable behaviours. Öktem, Aksoy and Öztürk (2023) and Sulaiman, Chan and Ong (2019) developed integrated models based on sustainable theoretical frameworks, investigating campus recycling variables that impact students' sustainability intentions (Izagirre-Olaizola, Fernández-Sainz, & Vicente-Molina, 2015). These studies found that recycling intentions and self-determined motivation can enhance students' campus recycling practices, while attitudes towards recycling, perceived behavioural control, and anticipated emotions affect their intention to adopt sustainable behaviours at home. Additionally, Moqbel et al. (2020) highlighted the role of education in shaping recycling habits and advancing campus sustainability initiatives.

The critical role of promoting recycling among students while balancing practical considerations with the objective of fostering sustainable behaviour is emphasized. Research on students' attitudes and recycling practices highlights the necessity for further investigation to fully understand their environmental attitudes and practices, thereby enhancing recycling effectiveness (Jiang, Sun, & Yu, 2024; Zhang et al., 2020). Insights from Izagirre-Olaizola et al. (2015), Akinwale (2022), and Pastor et al. (2020) reveal that university recycling policies significantly impact students' intentions to engage in sustainable behaviours. Accordingly, these findings inform the formulation of the fourth hypothesis.

H4: *Recycling influences students' intention to adopt sustainable behaviour.*

Green Buildings and Campuses

A school building unit prioritizes sustainability in its design and furnishings to address contemporary challenges. Universities enhance their green credentials by incorporating eco-friendly features such as solar power installations, geothermal systems, and rainwater collection. Green campus initiatives emphasize ecological management and environmental education, aiming to instil sustainable behaviours in students (Pardal et al., 2020; Pereira Ribeiro et al., 2021). These initiatives also involve integrating sustainability into curricula and campus policies, impacting students' perceptions and behaviours regarding sustainability. Studies by Hernández-Diaz et al. (2021), Fanea-Ivanovici and Baber (2022), and Adams et al. (2018) support the view that campus sustainability efforts significantly influence students' sustainable behaviours. Universities' initiatives to develop green campuses significantly influence students' intentions to engage in sustainable behaviour. By promoting green buildings and campus sustainability, universities foster positive attitudes, enhance awareness, and provide essential infrastructure, which collectively encourages sustainable practices among students. Therefore, the fifth hypothesis is proposed based on these findings.

H5: *Green buildings and campuses influence students' intention to adopt sustainable behaviour.*

Conceptual Framework

This research concludes that sustainable technologies directly impact university students' sustainable behaviours. Accordingly, it is essential to examine and quantify the effects of sustainable learning methods, renewable energy sources, recycling practices, and green buildings on students' intentions to adopt sustainable behaviours. Five hypotheses have been formulated to explore how the effective implementation of these sustainable technologies influences student behaviour (Alias et al., 2019; Rugatiri, Abidin, & Ismail, 2021). These hypotheses are conceptualized within the framework presented in Figure 1.

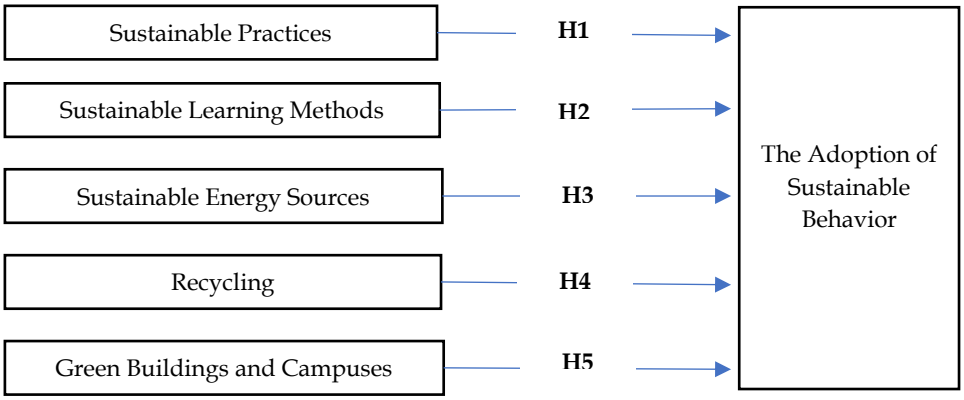

Figure 1: *Conceptual Framework.*

Methodology

The research is categorized as descriptive, as it seeks to elucidate the impact of sustainable technologies on students' adoption of sustainable behaviours. The study employs a

quantitative approach with a hypothetico-deductive methodology (Lacey, 1997), wherein hypotheses derived from the literature are empirically tested (Dodd & Epstein, 2011). Data collection was conducted using a structured questionnaire survey, designed to align with the research objectives. The questionnaire utilized a Likert-type scale (5 points, ranging from Strongly Disagree to Strongly Agree) to assess responses. It focused on key variables and was administered to university students, who participated voluntarily. The survey was distributed across two university campuses in northern Lebanon, with Lebanese students selected randomly through a convenience sampling technique. The questionnaire comprised thirteen items, equally distributed among the variables of interest. Specifically, five items were used to evaluate each of the following sustainable practices: sustainable learning methods, sustainable energy sources, recycling, and green buildings and campuses. These practices were treated as independent variables in the study.

Table 1

Measurement Scales

Variables / Dimensions	References	Items	Code
Sustainable Practices	(Barros et al., 2020; Chowdhury, Chowdhury, & Paul, 2022; Elkhwesky et al., 2022; Hamón et al., 2020)	Five Validated Items	S.P.
Sustainable Learning Methods	(Barros et al., 2020; Chen & Chen, 2022; Holloway & Mengersen, 2018; Müller et al., 2020; Trang, 2021)	Five Validated Items	S.T.
Sustainable Energy Sources	(Araújo, Nunes, & Curado, 2023; Leal Filho et al., 2019; Montoya & Perea-Moreno, 2020; Pastor et al., 2020; Tunji-Olayeni et al., 2023)	Five Validated Items	SES
Recycling	(Akindeji et al., 2019; Moqbel et al., 2020; Öktem et al., 2023; Sulaiman et al., 2019)	Five Validated Items	R
Green Buildings and Campuses	(Adams et al., 2018; Fanea-Ivanovici & Baber, 2022; Hernández-Diaz et al., 2021)	Five Validated Items	G.B.
The Adoption of Sustainable Behaviour	(Aguirre Sánchez et al., 2021; Alsaati, El-Nakla, & El-Nakla, 2020; Romero-Colmenares & Reyes-Rodríguez, 2022)	Five Validated Items	AGP

To assess the validity and reliability of the data, the Kaiser-Meyer-Olkin (KMO) measure and Cronbach's alpha were calculated. Exploratory factor analysis (EFA) employed principal component analysis (PCA) to identify a reduced set of dimensions that capture the relationships among variables. The KMO measure determines the adequacy of the sample for analysis, with values above 0.6 indicating poor and values above 0.7 indicating satisfactory sampling adequacy. The Kaiser criterion (eigenvalue > 1) was used to decide the number of factors to retain for each construct. Cronbach's alpha (α) was used to evaluate internal consistency, with a coefficient above 0.7 considered acceptable, reflecting higher reliability as the value approaches 1. Normality tests and PCA were conducted to validate the data. Data analysis was performed using SPSS, and the relationships between dependent and independent variables were examined through regression analysis, Cronbach's alpha, and Pearson's correlation (Deniz & Bagçeci, 2021).

Findings and Interpretations

An exploratory factor analysis was conducted to verify the reliability and validity of the conceptual framework. The analysis included two variable types: sustainable practices (five dimensions forming the independent variable) and students' adoption of sustainable behaviour (the dependent variable). Principal component analysis (PCA) with varimax rotation was applied to the collected data. According to Kaiser's criterion (eigenvalues > 1), a component was retained for each factor. The Cronbach's alpha values for each dimension were deemed satisfactory, as they consistently exceeded 0.5.

Construct Validation

Table 2

Sustainable Practices (Construct Validation)

Constructs	Items	(Factor Loadings)	KMO	(α)
S.P.	The university formed green clubs to organize green activities, such as planting trees around the campus.	0.869	0.737	0.758
Sustainable Practices	The university has implemented a green certification program that rewards students demonstrating exemplary efforts	0.778		
(Four Items Out of Five)	in promoting sustainability.			
	The university is rewarding students, demonstrating exemplary efforts in promoting sustainability.	0.669		
	The university is promoting recycling habits among students.	0.655		
S.T.	Instructors rely on Google Forms for tests to reduce paper usage.	0.748	0.746	0.698
Sustainable Learning Methods	Instructors use smartboards powered by renewable energy, making it easier for instructors to explain complex topics.	0.699		
(Four Items Out of Five)	Students are encouraged to use the PDF versions as an alternative to books.	0.698		
	Online gamification increases creativity in the classroom.	0.679		
GB	The university is adopting large windows in its sustainable building design to minimize energy consumption.	0.882	0.619	0.709
Green Buildings and Campuses	The university is obtaining environmental certification before any new campus construction.	0.769		
(Three Items Out of Five)	The university is broadening the shaded area by consistently planting trees on campus.	0.747		
R	The university collects food leftovers from the cafeteria for composting purposes.	0.770	0.650	0.664
Recycling	The university uses environmental strategies to reduce waste, such as giving away old exams to recycling companies.	0.759		
(Three Items Out of Five)	Universities direct their students to use only the required number of printed course papers.	0.718		
SES	The university provides options for organic food items on the cafeteria menu.	0.860	0.600	0.556
Sustainable Energy Sources	Solar panels are installed as an alternative to conventional electricity.	0.673		
(Two Items Out of Five)				
Total Variance Explained TVE			62.2%	
KMO			0.694	
Approx. Chi-Square			1217.116	
Sig.			0.000	
Determinant			0.18	

PCA, after applying varimax rotation, identified four dimensions of sustainable practices, explaining 62.2% of the variance. The Cronbach's Alpha for these dimensions was 0.793. For the Sustainable Practices dimension, four out of five items were retained. These items were adapted from scales developed by Hamón et al. (2020), Chowdhury et al. (2022), Elkhwesky et al. (2022), and Barros et al. (2020). The retained items demonstrated strong reliability with a Cronbach's Alpha of 0.758 and validity, indicated by a KMO value of 0.737. In the Sustainable Learning Methods dimension, four out of five items were retained. This dimension was measured using an original scale, incorporating items from Holloway and Mengersen (2018), Trang (2021), Chen and Chen (2022), Barros et al. (2020), and Müller et al. (2020). After purification, the scale achieved an internal consistency index (α) of 0.698 and a KMO of 0.746. The Green Buildings and Campuses dimension retained three out of five items. After purification, these items exhibited satisfactory reliability with a Cronbach's Alpha of 0.709 and a KMO value of 0.619. The Recycling dimension also retained three out of five items, based on scales from Alsaati et al. (2020), Aguirre Sánchez et al. (2021), and Romero-Colmenares and Reyes-Rodríguez (2022). The purified measure demonstrated acceptable reliability, with a Cronbach's Alpha of 0.664 and a KMO of 0.650. The Sustainable Energy Sources dimension retained two out of five items, showing adequate indicators with a Cronbach's Alpha of 0.556 and a KMO value of 0.600.

Table 3

The Adoption of Sustainable Behaviour (Construct Validation)

Items	Factor Loading
Awareness of sustainable technologies increases the implementation of sustainable practices in daily life.	0.791
The knowledge gained in class as a student increases the tendency to apply these practices in life.	0.694
Sustainable technologies enhance the classroom learning experience	0.646
Total variance explained TVE	50.8%
KMO	0.678
Approx. Chi-Square	63.584
Sig.	0.000
Determinant	0.813

The variable "adoption of sustainable behaviour" retained three out of five items, based on a scale adapted from Alsaati et al. (2020). After purification, these three items accounted for 50.8% of the explained variance, indicating that over half of the original data were preserved. A significant determinant value (> 0.05) confirmed the validity of these results. An item with insufficient representation of the identified single factor was excluded following varimax rotation. The final measure, consisting of the three retained items, demonstrated satisfactory indicators with a Cronbach's Alpha of 0.664 and a KMO of 0.650.

Correlation Matrix

Table 4

Correlation Matrix

						Collinearity Statistics	
Dimensions	**SP**	**ST**	**GB**	**R**	**SES**	**Tolerance**	**VIF**
SP Sustainable Practices	1					0.862	1.161
ST Sustainable Learning Methods	0.474**	1				0.861	1.162
GB Green Buildings and Campuses	0.530**	0.057**	1			0.982	1.018
R Recycling	0.368**	0.090**	0.030**	1		0.858	1.166
SES Sustainable Energy Sources	0.512**	0.359**	0.121*	0.007*	1	0.860	1.163
AGP Adoption of Sustainable Behaviour	0.556**	0.487**	0.354**	0.326**	0.266**	--	--

Pearson correlation analysis was conducted to examine the relationship between sustainable practices and the adoption of sustainable behaviour within Lebanese universities. The results revealed a significant positive correlation between these variables ($r = 0.556$), ($p < 0.001$), ($n = 310$). This indicates that increased implementation of sustainable practices is associated with a greater intention among students to adopt sustainable behaviour, reflecting a positive shift towards sustainability in this context.

Hypotheses Testing

Regression analyses were performed to test the hypotheses. Linear regression was used to examine how one or more quantitative independent variables explain the variation in the dependent variable. This analysis assessed the significance of the relationships and evaluated the extent to which the independent variables account for the variance in the dependent variable. The tolerances and variance inflation factors (VIFs) are within the recommended ranges (tolerance > 0.3 and VIF < 3.3), indicating low multicollinearity among the explanatory variables and suggesting a robust model. The results show that sustainable practices account for 68% of the variance in the adoption of sustainable behaviour ($R^2 = 0.68$). Thus, the five retained dimensions of the independent variables explain 68% of the variability in students' sustainable behaviour. Consequently, the equation predicting changes in the dependent variable is as follows:

= 2.253 + (Sustainable Practices* 0.590) + (Sustainable Learning Methods * 0.535) + (Green Buildings and Campuses * 0.305) + (Recycling * 0.510) + (Sustainable Energy Sources * 0.51).

The structural model met the fitness criteria established by Amini and Alimohammadlou (2021), Mardani et al. (2017), and Singhal et al. (2019). The root mean square error of approximation (RMSEA) was 0.01, and other fit indices, including the standardized fit index (NFI) of 0.971 and the comparative fit index (CFI) of 0.977, were above the recommended thresholds. These results indicate that the structural model demonstrates a good fit to the data.

Table 5

Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.253	0.403		5.596	0.00
	Sustainable Practices	0.590	0.070	0.574	1.293	0.00
	Sustainable Learning Methods	0.535	0.063	0.531	4.548	0.00
	Green Buildings and Campuses	0.305	0.048	0.340	6.366	0.00
	Recycling	0.510	0.063	0.509	4.165	0.00
	Sustainable Energy Sources	0.510	0.055	0.515	2.010	0.00
	R^2		0.682			
F	F test		10.407			

Table 6

Hypotheses Testing

Independent Variables	→	Dependent	Estimate	S.E.	C.R.	P	Results
Sustainable Practices	→	Adoption of Sustainable Behaviour	0.590	.045	6.503	0.000	Supported
Sustainable Learning Methods	→	Adoption of Sustainable Behaviour	0.535	.044	3.398	0.000	Supported
Green Buildings and Campuses	→	Adoption of Sustainable Behaviour	0.305	.043	4.350	0.000	Supported
Recycling	→	Adoption of Sustainable Behaviour	0.510	.041	5.958	0.000	Supported
Sustainable Energy Sources	→	Adoption of Sustainable Behaviour	0.510	.041	4.289	0.000	Supported

The RMSEA, CFI, and GFI are standard indicators for confirmatory factor analysis. Based on the obtained data, the model was deemed fit, with all factor loadings being significant. These indicators are used to evaluate the appropriateness of the model application, confirming that the scale is multidimensional. The composite reliability (C.R.) values surpassed the threshold of 1.96 (Amini & Alimohammadlou, 2021; Mardani et al., 2017). Structural equation modelling (SEM) was employed to test the model and hypotheses, utilizing SPSS and AMOS 25.0 for analysis. The hypotheses were assessed following the validation of the structural model. Multiple linear regression results, including BETA coefficients and p-values, were used to test the hypotheses. All hypotheses were supported, indicating that sustainable practices are effective predictors of students' adoption of sustainable behaviour ($p > 0.05$).

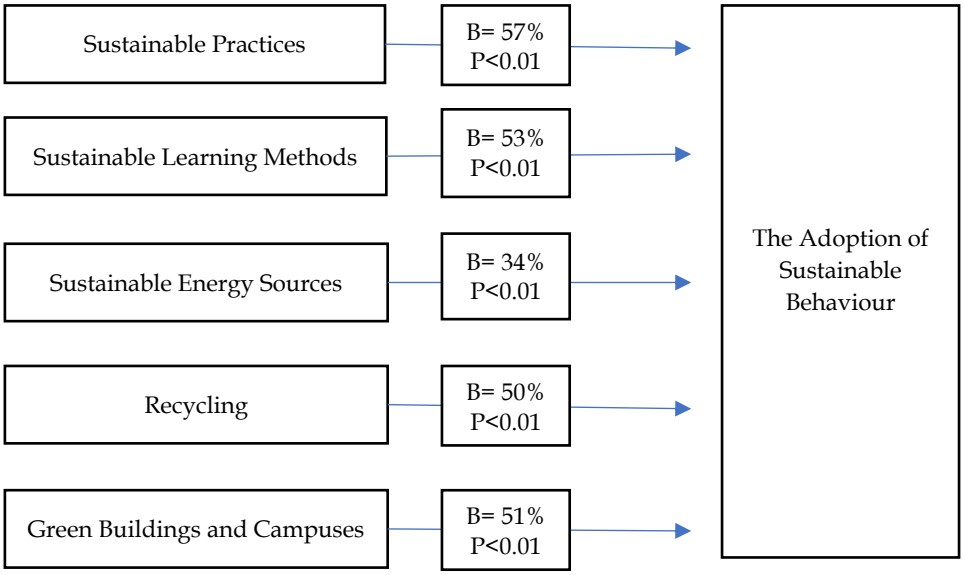

Figure 2: *Verified Model (β Coefficient, p<0.00).*

The findings indicate that the application of sustainable practices has the most substantial impact on students' intention to adopt sustainable behaviour, with a standardized coefficient (β) of 0.590 and a significance level (p) less than 0.001. This suggests that a 59% increase in the implementation of sustainable practices correlates with a 57% increase in students' intention to engage in sustainable behaviour. These results validate Hypothesis 1 (H1), which posits that sustainable technologies significantly influence students' intentions to adopt sustainable behaviour. Lebanese universities are actively engaging in green initiatives, such as campus tree planting and rewarding students who promote sustainability. These efforts are complemented by encouraging recycling and adopting green certification programs, which collectively enhance sustainability efforts. Sustainable learning methods also exhibit a notable impact on students' adoption of sustainable behaviour, with a β of 0.535 and a p-value less than 0.001. This implies that a 53% increase in sustainable learning methods is associated with a 53% increase in students' intention to adopt sustainable behaviour. These findings support Hypothesis 2 (H2), which asserts that sustainable learning methods significantly affect students' intentions to adopt sustainable behaviour. Instructors are contributing to sustainability by reducing paper usage through the use of Google Forms for exams and renewable energy-powered smartboards for teaching. Additionally, students are encouraged to use PDF versions of textbooks instead of printed copies, further supporting the adoption of sustainable teaching practices. Green buildings and campuses also significantly influence students' intention to adopt sustainable behaviour, with a β of 0.305 and a p-value less than 0.001.

A 30% increase in green buildings and campuses is linked to a 4% increase in students' intention to engage in sustainable behaviour. This supports Hypothesis 5 (H5), which proposes that green buildings and campuses affect students' intentions to adopt sustainable behaviour. The development of green spaces and sustainable campus facilities

plays a crucial role in improving students' quality of life and encouraging their participation in sustainability initiatives. Lebanese universities are enhancing their green infrastructure by incorporating expansive windows in building designs to reduce energy consumption and increasing shaded areas through campus tree planting. These green campus initiatives, including campus policies, transportation management, and energy resource consumption, contribute to increasing students' intention to adopt sustainable behaviour.

Recycling exerts a statistically significant direct impact on students' adoption of sustainable behaviour, with a standardized coefficient (β) of 0.510 and a significance level (p) less than 0.001. This indicates that a 51% increase in recycling activities is associated with a 50% increase in students' intention to adopt sustainable behaviour. These results support Hypothesis 4 (H4), which posits that recycling significantly influences students' intention to engage in sustainable behaviour. Lebanese universities are actively implementing recycling practices to promote sustainability. These practices include collecting food scraps from cafeterias for composting, minimizing the use of printed course materials, and recycling used papers and exams. Such recycling policies play a crucial role in reducing environmental waste and significantly impact students' sustainable behaviour. Additionally, students' recycling behaviours are influenced by their perceived behavioural control and subjective norms.

It has been observed that students' intentions to use reusable cups are significantly influenced by green university standards, with campus initiatives such as waste classification and recycling programs promoting sustainable recycling practices and supporting the circular economy. Integrated models, incorporating theories such as the Theory of Planned Behaviour and Self-Determination Theory, underscore the role of self-determined motivation, attitude, and perceived behavioural control in shaping recycling intentions and behaviours. Furthermore, sustainable energy sources have a substantial positive effect on students' adoption of sustainable behaviour, as indicated by a standardized coefficient (β) of 0.510 and a significance level ($p < 0.001$). This suggests that a 51% increase in the adoption of sustainable energy sources correlates with a 51% increase in students' intention to engage in sustainable behaviour. Lebanese universities are responding to this by installing solar panels to replace traditional electricity sources, thereby reinforcing the positive influence of sustainable energy on student behaviour.

Lebanese universities are actively promoting sustainable lifestyles among students through a range of applied strategies and educational initiatives. These institutions emphasize sustainable technological practices, including recycling and waste reduction, to enhance students' commitment to sustainable behaviour. By integrating sustainability into their curricula and institutional culture, universities not only underscore their dedication to environmental stewardship but also embed sustainable principles within academic programs. This includes incorporating sustainable learning methods to provide practical education on eco-friendly practices and integrating outdoor activities into environmental-focused courses. Lebanese universities thus foster sustainable behaviour by embedding sustainability into their educational framework, ensuring students have accessible and engaging opportunities to participate in environmentally responsible activities, and demonstrating a strong commitment to eco-friendly practices.

Universities play a crucial role in shaping students' adoption of sustainable behaviours, particularly through the promotion of sustainable energy sources. The commitment of a university to sustainability significantly impacts students' lifestyles and habits, encouraging engagement in sustainability-driven entrepreneurship. Factors such as understanding the Sustainable Development Goals and university support further influence students' involvement in sustainability activities. Education on sustainability initiatives effectively enhances pro-environmental behaviours and attitudes, such as recycling and energy conservation. Additionally, sustainable learning strategies contribute to developing students' knowledge, beliefs, and behaviours aligned with sustainability, with their effectiveness varying by demographics, educational environment, and exposure. Overall, integrating sustainable practices into curricula and learning strategies significantly influences students' intention to adopt sustainable behaviours.

Conclusion and Recommendations

This article assessed the impact of sustainable technologies on Lebanese students' intentions to adopt sustainable behaviours, focusing on technological solutions rather than teaching practices. Findings indicate that sustainable technologies positively influence students' intentions. The application and evolution of these technologies, including sustainable learning methods, energy sources, recycling, and green campuses, continue to shape student behaviour. Universities contribute to sustainability through the concept of a sustainable campus, which aims to enhance energy efficiency, reduce waste, and mitigate environmental degradation. Research confirms that sustainable campus initiatives—such as energy efficiency, green buildings, and waste management—effectively support students' adoption of sustainable behaviours. To promote these behaviours, universities should integrate sustainability into their curricula and activities, creating informed and responsible citizens. Educational institutions are encouraged to implement long-term projects that foster biodiversity and to engage students in practical sustainability practices, such as waste sorting and composting. Instructors should leverage their influence to promote energy conservation and eco-citizenship. Additionally, universities should establish clear waste reduction goals and encourage students to participate in sustainability initiatives, including proper waste management and recycling practices. Additional practices that universities could promote include:

- Avoiding plastic products, particularly by opting for filtered tap water instead of bottled water.
- Prioritizing eco-friendly materials.
- Favouring products made from recycled materials.
- Choosing environmentally responsible school supplies.
- Selecting local and sustainably sourced materials.

However, it is important to acknowledge the limitations of this study. Firstly, the use of a quantitative approach restricts the analysis to students' perspectives alone. Future research should incorporate mixed methods, including qualitative interviews, to capture the viewpoints of university managers. Additionally, the sampling method, which involved randomly selecting students, may not fully represent the population. Employing a stratified random sampling technique based on students' schools and majors could

provide more nuanced insights. Another challenge is the limited interest among students in consistently adopting sustainable practices, which may be influenced by their environment and familial education. Future studies should explore the perceptions of eco-friendly behaviours among younger generations, such as primary and secondary school students, and examine how educational institutions' geographic locations and specific educational and political contexts impact the adoption of green practices.

Credit Authorship Contribution Statement

Basma Bchennaty: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Mazen Massoud:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Abir Fawal:** Resources, Validation, Visualization. **Muhammad Nauman Khan:** Project administration, Supervision, Writing - review & editing.

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

Data Availability

The data that has been used is confidential.

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