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Multidirectional paths to achieve the SDG-13 from Mexican universities: interdisciplinary, sustainable lifestyles and green technology

ODS 13 en las universidades mexicanas: los caminos multidireccionales para lograrlo

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Resumen

El objetivo fue analizar las acciones climáticas de las universidades mexicanas para identificar las rutas que permitan su reorganización estratégica para contribuir al logro del ODS 13 (acción por el clima). La investigación fue cualitativa; se analizó y categorizó por frecuencias de co-ocurrencia la experiencia de educación climática de 15 universidades públicas y privadas mexicanas, y se analizaron en profundidad 43 iniciativas universitarias destacadas. Los hallazgos mostraron tres líneas de acción climática: educación interdisciplinaria, modos de vida saludable y transferencia de tecnologías verdes. Así, la gestión de la sostenibilidad debe seguir un enfoque transversal porque las comunidades interdisciplinarias son capaces de institucionalizar formalmente los tres pilares de la sostenibilidad –social, ambiental, económica- con base en la colaboración.

Palabras clave: *ODS 13, educación sustentable, acción climática universitaria.*

Abstract

This paper aimed to analyze the climate actions of Mexican universities to identify the multidirectional paths that would allow the strategic reorganization to foster to the achievement of SDG 13 (climate action). The research was qualitative; the sustainability experiences of 15 Mexican public and private universities were analyzed and categorized by frequencies of co-occurrence, and 43 outstanding sustainability initiatives were deeply analyzed. The findings showed three types of university action (environmental practice, mitigation and adaptation action). Furthermore, three reinforcing paths of action were identified: interdisciplinary education, sustainable lifestyles, and green-technology transfer. Thus, climate action management could follow a collaborative, transversal and interdisciplinary approach to foster a sustainable ecosystem beyond the university walls.

Keywords: *SDG 13, sustainability education, university climate action.*

JEL: M39, O18, Q56

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Introduction

The social demand to implement national action plans to advance the Sustainable Development Goals (SDGs) under different economic, social, cultural, and political contexts has increased (Leal et al., 2020; Sachs et al., 2019); nevertheless, However, there is a strong challenge to put into operation specific actions to operationalize the SDGs (McCowan et al., 2021; Ridhosari & Rahman, 2020). Many documents have proposed programs to transform productive, social, and public organizations with a sustainability approach by defining specific actions to align with the SDGs (UN, 2022; Sachs et al., 2019). One of the most common strategies is the collaboration between governmental, educational, and private organizations and civil society to support the sustainable development (Álvarez & Palacios, 2021; Molthan-Hill et al., 2019). However, the SDGs achievement requires an integrated network of actors that share resources (e.g., knowledge) to accelerate the attainment of the SDGs (Álvarez et al. 2023; Leal et al., 2022).

Although sustainable development (SD) seems to be mainly the responsibility of governments and private organizations, education institutions are also accountable for the attainment of the sustainability development goals (NU, 2022), particularly SDG-4 (Quality Education), but also SDG-12 (responsible production and consumption), SDG-8 (decent work and economic growth), and SDG-13 (climate change). Education for sustainability has emerged as a significant movement in higher education in recent years (Álvarez et al., 2024; Leal et al., 2020). However, there is enormous variability in how the agenda for sustainability education has been taken up by individual institutions partly due to how high education institutions (HEI) conceptualize, operationalize, and commit to the promotion of sustainability with action ranging from promoting specific land and resource management processes through an interdisciplinary perspective (Leal et al., 2022; Holdsworth & Sandri, 2021; McCowan et al., 2021).

This research focuses on how SDG 13 has been approached by universities given the urgency to mitigate and adapt to the impacts of climate change. According to literature review, SDG-13 allude to systematize the efforts to reduce the impacts of climate change -for instance, greenhouse gas emissions- and to adjust our lifestyle -for example, by reducing the vulnerability towards hydrological disasters- (Pearson et al., 2021; Fuente et al., 2019; UN, 2015). Despite the lack of forceful actions and policies to develop mechanisms for increasing the capacity to effectively plan and manage climate change (Xiang et al., 2019; Grigoroudis et al., 2016) among the social (Goldberg et al., 2020) and productive sectors (Mazutis & Eckardt, 2017; Finke et al., 2016), the intervention of the University to meet the targets of SDG has shown hopeful results (Álvarez et al., 2023; Leal et al., 2022; McCowan et al., 2021).

The University role in sponsoring climate change actions is crucial because of its institutional credibility and social function, and its potential capacity to provide environmental education, raise environmental awareness, and research capabilities to generate and transfer green technologies, contribute to strengthening the resilience and adaptive capacity of communities prone to natural disasters, and propose business models to recover/preserve land and water resources (McCowan et al., 2021; Pearson et al., 2021; Reichert, 2019). Social pressure has increased and certainly influenced universities to implement environmental programs aimed at contributing to SDG 13 (Álvarez et al., 2023; Chen et al., 2018). According to Leal et al., (2020), the discussion on education for sustainability in higher education dates to the nineties; however, the formalization of policies, programs, and action plans to promote sustainability was consolidated between 2005 and 2014.

The literature reports multiple university's efforts and experiences to enhance climate action (Sanchez et al., 2021; Zguir et al., 2021; Wamsler, 2019). However, there is an important gap between the design of curricula and the demands related to sustainability education, especially those that impact climate change (Chen et al., 2018). Meaningful learning objectives and contents, and the introduction of new pedagogic methods that empower learners to include sustainability principles in their professional careers are required (UNESCO, 2017). Moreover, the literature shows that sustainability management impacts the practice of academic communities and their environment because inter-organizational collaboration generates

opportunities for mutual learning, consequently, there is a greater incidence on the environment (Oke, 2023; Alirez et al., 2022). The opportunities to strengthen the university climate action are multiples, therefore, the study of this social phenomenon in Mexico contributes to understanding how to enhance the participation of universities in Latin-America.

Successful environmental projects and highly heterogeneous environmental concerns between communities and socioeconomic contexts in Mexico were found; however, most these projects have limited results despite institutional efforts (Álvarez et al., 2024; Fuente et al., 2019; Montero, 2015). This research acknowledges the University is a key enabler for sustainability and is capable of supporting actions against climate change (UNESCO, 2017), and Mexican universities are pertinent study object because of the Latin American countries are considered a living lab for research due to their social, cultural, and economic profile (Aguinis et al., 2020). Therefore, this paper aims to analyze the current state of implementing climate action at Mexican universities, and how the success of these implementation efforts can be fostered further to contribute to the achievement of SDG 13 (climate action) through inter-disciplinary and cooperative projects, institutional programs, and community practices.

Theoretical framework

The sustainable perspective of the universities considers enhancing environmental values, environmental awareness, respect for megadiversity (Fuente et al., 2019; Goldberg et al., 2020), and the pursuit of equitable welfare (Zhang, 2020; Chen et al., 2018; Dyer & Dyer, 2017; Slawinski et al., 2017). Environmental education has had two axes of action: a) courses or workshops taught in the university's educational programs; b) university’s practices –such as the design of sustainable buildings and building of green campuses, among others- (Leal et al., 2022; Molthan-Hill et al., 2019). The initial focus of these environmental practices is mainly oriented toward the mitigation of climate change. Moreover, climate actions focus on supporting the public, social, and productive sectors to fulfill environmental policies by designing and transferring environmental practices aimed at reducing the use of resources in productive processes, for example through circular economy actions (Street et al., 2022; Sharifi, 2021).

Sustainability education and management in universities has steadily grown with climate action as one of the key subcategories of environmental sustainability and an emerging field to be included in the educational programs (Salovaara et al., 2020). Sustainability education has advanced in four stages. The first one is educational to supply knowledge, skills and competencies to enable the student participation in building a sustainable and sustainable futures. Sustainability has become part of the education programs, from courses and workshops at the undergraduate level to sustainability science programs (Zguir et al., 2021). The second phase refers to the social responsibility of universities. Economic, environmental, and social aspects are included in the university’s internal decisions and operational processes. The implementation of pro-environmental actions, from the reduction of energy, water, and waste to the design of sustainable buildings and green campuses are examples of the university’s environmental responsibility (Wamsler, 2019).

The third is what Arocena and Sutz (2021) named “social outreach” that acknowledges universities are centers for research and education with the potential together with other actors to contribute to regional sustainability through formal, non-formal, and informal knowledge transfer; increase the environmental awareness, perceived behavioral control (self-efficacy and perceived control over the performance of behavior) and consumer effectiveness; and facilitate environmentally friendly behaviors (e.g. providing proper sites to collect and separate residues) (Sanchez et al., 2021). Finally, there is the emergent role of transforming directly or indirectly the social reality through interdisciplinary collaboration with private, public and social institutions to accelerate sustainable development, and enable universities to contribute to welfare by economic, environmental, cultural, and social issues of local and global communities (Álvarez & Palacios, 2021; Purcell et al., 2019).

Based on the literature review, climate action from the University was conceptualized as the set of actions directed toward the preservation of the natural, biocultural, and social environment with a collaborative approach and a shared vision of a sustainable future (Boyd et al., 2022; Street et al., 2022; Dube, 2021; Sharifi, 2021; Coscieme et al., 2020). It is important to highlight that these actions must guarantee economic sustainability, transcend individual interests, be integrated into the institutional culture, and the generation of green technologies, business models, sustainable education, and the reduction of university's operations on the environment. Based on the literature review, Table 1 outlines the principal dimensions of sustainability philosophy and climate action.

Table 1

Dimensions of the sustainability philosophy and climate action

	Sustainability	
Climate action	Ethical and social perspective driving climate policies and business models	Pearson et al. (2021), Sharma et al. (2020), Xiang et al. (2019), Ritala et al. (2018).
	The University has a critical role to play in moving society towards sustainability	Ridhosari & Rahman (2020), Zhang (2020), Chen et al. (2018), Dyer & Dyer (2017), Slawinski et al. (2017)
	Sustained social/community engagement and research/projects to address climate action	Karrasch et al. (2022), Leahey & Barringer (2020), Goldberg et al. (2020)
	Approach [mitigation or adaptation] [inter or transdisciplinary]	Boyd et al. (2022), Karrasch et al. (2022), Street et al. (2022), Dube (2021), Sharifi (2021), Coscieme et al. (2020).

Source: by the authors.

Based on the above, the sustainability, the climate action, and the role of universities are interrelated. Universities have restructured themselves at different levels to respond to the challenges of economic, social, and environmental sustainability (Álvarez et al., 2024; Leal et al., 2022; Arocena & Sutz, 2021). The climate action (mitigation and adaptation) has been part of this university restructuring, which is relevant because the universities are crucial in fostering the collaborative and co-responsible attitudes, and critical thinking in decision makers (Álvarez et al., 2024; Filho et al., 2023). Moreover, new educational approaches based on interdisciplinarity and transdisciplinary have been development to achieve multidirectional learning processes or using emerging technologies such as artificial intelligence in socioenvironmental projects (Beckmann & Schaltegger, 2020; Laasch et al., 2020).

In this research, the interdisciplinary approach is conceptualized as the integration of several disciplines that contribute to the generation and application of knowledge from different areas to produce new scientific knowledge to contend with climate change. The integration of different knowledge sources, that is of an interdisciplinary perspective is required (Dube, 2021; Leahey & Barringer, 2020). The transdisciplinary approach is different because the whole process of knowledge creation is collaborative (space-time duality), and it does not require a final integration process because the transdisciplinary knowledge creation is articulated with public policies, technologies, and communities of practice of different sectors of the society (Karrasch et al., 2022).

Materials and methods

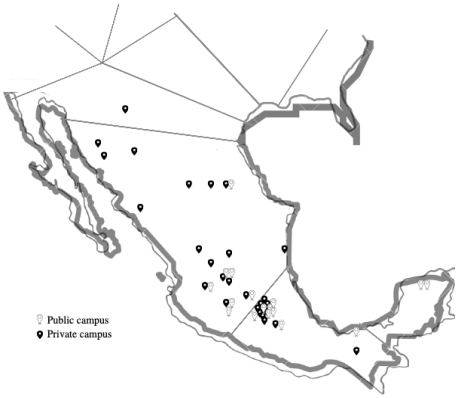
The research was exploratory with an explanatory emphasis as it examines the universities' actions to ascertain their contribution to mitigating and adapting to climate change. The methodological approach was qualitative based on a phenomenological and hermeneutic analysis, which used collected data and systematically coded (Clifford, 2003) to unveil social trends and enhance the comprehension of the universities' role toward climate action. The validation had two paths; the internal through the triangulation

of data; the external through analytical generalization (Yin, 2013). The literature review used search keywords "sustainability practices", "climate action", "sustainable behavior", "sustainable factors", "sustainable drivers" and "sustainable intention". The keywords University and "Higher Education Institutions" were added to strengthen the search. The methodological process comprised two phases to analyze the categories and paradigms defined by the universities, and the scheme of appropriation of the university's communities that translates these normative guidelines into sustainable practices.

The first phase encompassed the deep study of the sustainability statements and reports of 15 Mexican universities. These institutions were selected through purposive sampling (Patton, 2015). The basic inclusion criteria were the following: 1) availability of published information about the sustainability plans and actions and 2) a heterogenous sample of universities in terms of size, scope, and funding. Figure 1 shows the geographical distribution of the campuses of the sampled universities. 73% of the studied universities were public institutions and the rest were private; 60% had a local scope, 7% regional and 33% national. The information was obtained from official WEB sites, indexed scientific papers about the commitment and social responsibility towards climate change of Mexican universities, and grey literature including the thesis and proceedings of academic conferences. The highest proportion of documents (91%) discussed sustainability programs, projects, or implemented actions, and the rest described how the success of these implementation efforts was monitored and evaluated.

Figure 1

Geographical distribution of the selected university campuses



Source: by the authors based on information from institutional WEB sites.

In the second phase of the methodology, a systematic analysis of 43 university initiatives of climate action from four local public universities of Mexico –Guadalajara, Guanajuato, Nuevo León and Yucatán- that involved the participation of students, professors, and management were analyzed in detail. The selection of these was through an intentional sampling (Patton, 2015) based on two selection criteria. The first, the institutions of these territories in the ANUIES report evidence significantly sustainable activity (ANUIES, 2020). The second, the complex environment of these universities has had highlight features; Guadalajara, Guanajuato and Nuevo León have had a strong industrial vocation and strong environmental challenges (Álvarez et al., 2018); Yucatán has been acknowledged as an innovation pole and has occupied the eighth national place for its green-scientific productivity (Porto et al., 2019).

This analysis allowed the interpretation of climate change interventions as a social phenomenon. Although the qualitative strategy limits the generalization of results (Clifford, 2003), the diversity in the

profiles of the units of analysis allowed a broad description of how the university influences the community through its sustainable contributions. The global hermeneutic unit was analyzed to identify key terms and phrases (Clifford, 2003); the codes associated with the most representative categories of climate mitigation (e.g., reduction of water, energy, and waste management) were analyzed through frequency tables of co-occurrence in ATLAS.ti® v.8.4.5. In addition to the pro-environmental practices formally defined by the institutions, the interaction between the university with key ecosystem actors (e.g. the local community), the public-private alliances, and the expected social, environmental, and economic internal and external impacts of climate change mitigation actions were examined.

The replicability of the research procedure was ensured through thorough documentation, recording of all data sources, and coding decisions. Coding proceeded as follows: 1) initial codes were developed using the keywords themselves; 2) these codes were grouped and categorized using word cloud analysis, and the coding schemes included calculating co-occurrence frequencies. Next, these were synthesized to proceed with the construction of the semantic network. Finally, the multilayers semantic network was built. This complex network has spheres that represent the sustainability categories, lines to show the spheres' connection, and a coded color to indicate each layer of the network. The size of the spheres was defined by the frequency of co-occurrence in the semantic analysis. The sphere-connecting lines show different types of scalar connections; thus, these are not shown as arrows. Although the coded color shows the three main connection-layer based on predominant frequency, these three layers link with each other because of the connection categories that were found in each layer (multidirectional paths).

Findings and discussion

Institutional sustainability approach

A strategy identified for all cases was the formation of a specialized area responsible for developing and monitoring the university's environmental actions. This organizational unit is acknowledged as the Sustainability Board, Green Office, Sustainability Office, Sustainability Services Office, Socio-environmental or Co-responsibility Office, and Social Impact & Sustainability. Three sustainability tactics were identified: backing environmental practices (e.g. recycling) among the community and in operations (e.g. using intelligent light switches), assessment of pro-environmental action (e.g. measuring water and energy savings), and low-carbon individual choices for climate action. According to Hampton and Withmarsh (2023), these choices are related to the reduction of greenhouse emissions by using renewable energy sources, changing to non-motorized transportation modes, reducing consumption, and influencing social groups to adopt sustainable lifestyles. The three broad tactics were identified in the 15 institutional discourses: the level of the actions (institutional versus campus level), the periodicity of measuring the effectiveness of pro-environmental actions and revising them, and the assignment of specific budgets.

The low capabilities of the University to develop collaborative projects with external organizations were evidenced by the low frequency of the category; thus, increasing the number of joint projects is a relevant challenge. Particularly, the participation of the universities in joint projects under international agreements for environmental care was extremely low. The Mexican Alliance for Climate Action (ACA-MX), part of the global initiative of the World Wildlife Fund (WWF) was cited as an example, but without evidence of the specific role of the university in the alliance. Nonetheless, the participation of the university community in work teams involved in the proposal of environmental laws and local public policies was high. This is a highlight because the literature review show that the sustainability projects represent a research opportunity at disciplinary, interdisciplinary, and transdisciplinary levels to develop green technologies, especially around resource and energy efficiency, design theory-based interventions to promote environmental awareness and efficiency at the university and regional level, and new business models related for example to circular economy (Karrasch et al., 2022; Goldberg et al., 2020; Leahey & Barringer, 2020).

Most university projects were mainly focused on increasing the environmental knowledge and awareness of the university community. Some projects showed the designing social interventions to reduce carbon footprint (mitigation) and others used theoretical frameworks to understand how behaviors and habits become established, adopted y can be transformed. Only simple behaviors such as waste recycling and the use of energy-saving bubbles (LED) in university facilities were commonly reported. Other behaviors such as reducing the consumption of energy, changing to renewable energy sources (e.g., photovoltaic panels), cutting transportation fuel, and decreasing consumption of goods were reported only by a few campuses.

A high frequency of learning units –courses, workshops, and projects- related to environmental sustainability or social responsibility at the undergraduate and graduate levels were recorded. The curricular content was difficult to assess; however, the analysis by title of learning unit coincided with the six domains of individual choice for climate action of Hampton and Whitmarsh (2023) –citizenship, energy, food, influence, shopping and transport-. Based on dense description, Table 2 shows the key categories that emerged from the systematic analysis, ordered by its relevance to conceptualizing sustainability and climate action. It is highlighted that some categories were integrated by relevant subcategories –for instance, welfare: corporate citizenship, community commitment, social responsibility, sustainable territories, sustainable communities, or economy was correlated with circular models, green, social, share-.

Table 2

Categorization of institutional sustainability

Category	Frequency	Category	Frequency
Natural resources	0.2195	Biodiversity	0.0976
Technology	0.0732	Digital society	0.0724
Welfare	0.1708	Ecosystem (ambiance)	0.1215
Economy	0.0962	Environmental	0.0951
Responsible consumption	0.2244	Education (training)	0.0244

Source: by the authors.

Pro-environmental practices and climate actions were identified based on the analysis of dense descriptions. The areas of knowledge were distributed among the following disciplines and schools: engineering (22%), economic and management science (18%), social and political science (18%), sustainability science (14%), and others (28%). The analysis showed interdisciplinary teamwork had a significant frequency of co-occurrence. When the thematic categories of climate action were compared across disciplines, two of the main domains of climate action (energy management and mobility) were led by engineering, mainly oriented to technology and innovation and in seeking to integrate issues of sustainability into professional education courses.

Table 3 shows the frequency of co-occurrence of the main concerns demonstrated by the universities' actions and practices: 57% of the activities focused on energy, water, and waste management while the lowest frequencies correspond to digital citizenship, cultural influences and pollution reduction. Furthermore, statements regarding the use of social media to share green technology innovations and generate public interest in environmental protection had a high frequency and are acknowledged as a new strategy to catch the attention of the young generation that is more environmentally conscious and technology proficient. This is coincided with Oke (2023), who assure that the technology innovations help to achieve and promote sustainability behaviors. According to Zhang (2020), social technologies –digital competencies and infrastructure- and institutions are key components to achieving multidimensional sustainability. However, the adoption of these technologies requires open, free, and unlimited access to the Internet and

technological devices; this represents a strong challenge to Mexico (and Latin America) due to their significant educational lags and student communities with deeply heterogeneous resources.

Table 3

Level of environmental practice and climate action

Category	Subcategories	Frequency
Energy	Eolic, solar, and electrical energy Efficiency, consumption monitoring Renewable or green energy	0.2043
Water	Accessibility as a Human Right Efficiency, consumption monitoring Infrastructure from hoses or taps to treatment plants	0.1429
Waste management	Urban management of hazard residues from academic labs Handling and safe disposal of electrical and electronic scrap Decentralized composting in dwellings Recycling	0.1836
Environmental governance	Green campus Living labs for technological or social development Green entrepreneurship: social or ecological sustainability initiatives. Sustainability innovation projects (multi and interdisciplinary) Participatory territorial planning	0.1020
Responsible consumption	Ecological footprint Plastic reduction Plastic-free	0.1020
Ecotechnologies	Rainwater harvest Bioclimate buildings	0.0816
Biodiversity conservation		0.0816
Mobility	Share Hybrid	0.0408
Digital citizenships	Electronic management Digital learning to SDG	0.0204
Cultural heritage	Vernacular knowledge Indigenous lore	0.0204
Pollution reduction		0.0204

Source: by the authors.

According to the analysis, climate actions are diverse and not always institutionalized because of the highly heterogeneous characteristics of the universities. The findings showed all institutions offer teaching on climate change; however, climate teaching is restrained to the natural or environmental sciences programs for 93% of the institutions. The main climate change actions include research projects, teaching/training programs, community-related programs, and academic publications.

Sustainable communities approach

The university initiatives studied to involve the participation of students, professors, and management. The formation of interdisciplinary teams was part of 82% of the initiatives and was acknowledged as a key enabler for the creation of approached sustainability from a holistic perspective. According Dube (2021), Coscieme et al. (2020), Leahey and Barringer (2020), interdisciplinary collaborative projects have great

potential to generate high-impact research with better practical results because of the integration of knowledge to understand biophysical processes, the structure and operation of ecosystems, institutional processes, and the cultural, economic, and political elements of the socio-technical systems that influence environmental decisions and behaviors. The nature of the projects was correlated with exogenous social and physical influences and cultural patterns; in the most cases, the low environmental community participation was alluded.

The stakeholders that triggered most of the initiatives were professors and student groups, although at least one of the private universities declared a top-down approach. In general, the initiatives analyzed promote awareness of the biophysical environment (issues and possible solutions) and the active participation of students through systematic activities focused on the preservation of natural resources, adoption of sustainable lifestyles, and the foreseeing of social welfare**.** These findings coincide with Leal et al. (2022) and McCowan et al. (2021), who assure that the climate action of universities is fundamental to encourage respect for the environment, improve perceived environmental efficiency, influence consumption decisions, and reduce social inequalities in surrounding communities.

The analytic results showed an increasing trend in the climate actions led by university students. The initiatives were classified into two general groups: the first refers to endogenous tactics that include for example environmental awareness campaigns or research projects, and the second refers to exogenous tactics, social interventions, and interinstitutional projects such as the Inclusive Recycling Model that organizes and formalizes the activities of urban recyclers in the surrounding community of the campus of one of the universities. This finding is relevant because climate change actions focus on the practical efforts to balance human welfare with environmental care supported by the different actors of the ecosystem (Álvarez et al., 2023; Pearson et al., 2021; Reichert, 2019).

Actions such as reducing the plastic footprint, harvesting rainwater, encouraging car sharing, reducing car use, increasing the use of eco-bicycles, building green walls with low-water plants, growing vertical gardens, reducing the generation of solid waste, recycling –plastic, paper and other materials-, were among the most frequent actions reported by universities as sponsored by student teams. The reduction of the plastic footprint was a widely pro-environmental action triggered by the university community's concern about the environmental harm generated by the high consumption of bottled drinks in disposable plastic containers. The reduced use and reuse of disposable bottles was mentioned as notorious among students, nevertheless, the use of disposables in university cafeterias was mentioned as very high. This finding is added to debate around the problem of the use of plastics and the lack of actions to reduce the greenhouse gas emissions caused by plastics and the low interest of people to change their shopping habits to actively avoid plastic packaging (Ridhosari & Rahman, 2020; Montero, 2015).

Regarding the reduction of solid waste, evidence of medium to high environmental action was found. The presence of garbage separation bins and the training of the university community about the shared responsibility to reduce solid waste agree with Ridhosari and Rahman (2020) who recognized these strategies motivate collective climate action. Low responsibility of the university community about waste disposal was reported in despite of recycling and reuse are the most common green initiatives reported by universities. Water conservation and reuse were among the least extended pro-environmental actions. Poor management of water was shown for example by the excessive water consumption of automatic irrigation systems without proper maintenance. Actions aimed to decrease energy consumption were practically non-existent and are of low interest to students.

The analysis of the information showed that there are individual efforts to mitigate climate change, nevertheless they are not well coordinated across schools and through collaboration with local private and public organizations. Thus, these climate actions have a limited lifetime (the school cycle) and impact. The taxonomy of university initiatives shown in Table 4 signals the construction of paths to harmonize climate action with the sustainability spheres.

Table 4

Taxonomy of university initiatives

Category	Frequency	Category	Frequency
Institutional	0.5676	**Environmental management**	0.1081
Environmental education		Preventive action	
Reforestation		Mitigation action	
		Socioenvironmental commitment	
		Interaction - productive sectors	
Urban sustainability	0.1061	**Digital sustainability science**	0.0811
Environmental education		Social communication	
Preventive action		Training (adaptation and mitigation)	
Water	0.0801		
Environmental education			
Preventive action			
Culture			
Mobility	0.0270	**Biodiversity**	0.0229
Preventive action (e.g. Eco-bikes)		Preventive action	

Source: by the authors.

The involvement of the university community in pro-environmental projects defined at the institutional level (top-down stream) seems to be decisive in achieving meaningful results. These findings agree with McCowan et al. (2021) and Leal et al. (2020), who assure that the universities can accelerate the ecosystem's climate motivation by promoting sustainable lifestyle behaviors, purchasing energy-saving products, reducing and conserving energy and water, and reducing/sorting waste. Moreover, it was evidenced that the community involvement is a key enabler for climate action provided environmental compromise and trust in the efficiency of climate actions increase. Nevertheless, Goldberg et al. (2020), VanDyke and Lee (2020) make certain that the appropriate communication of the quantitative impact of climate actions is essential for the engagement and collaboration of the university communities.

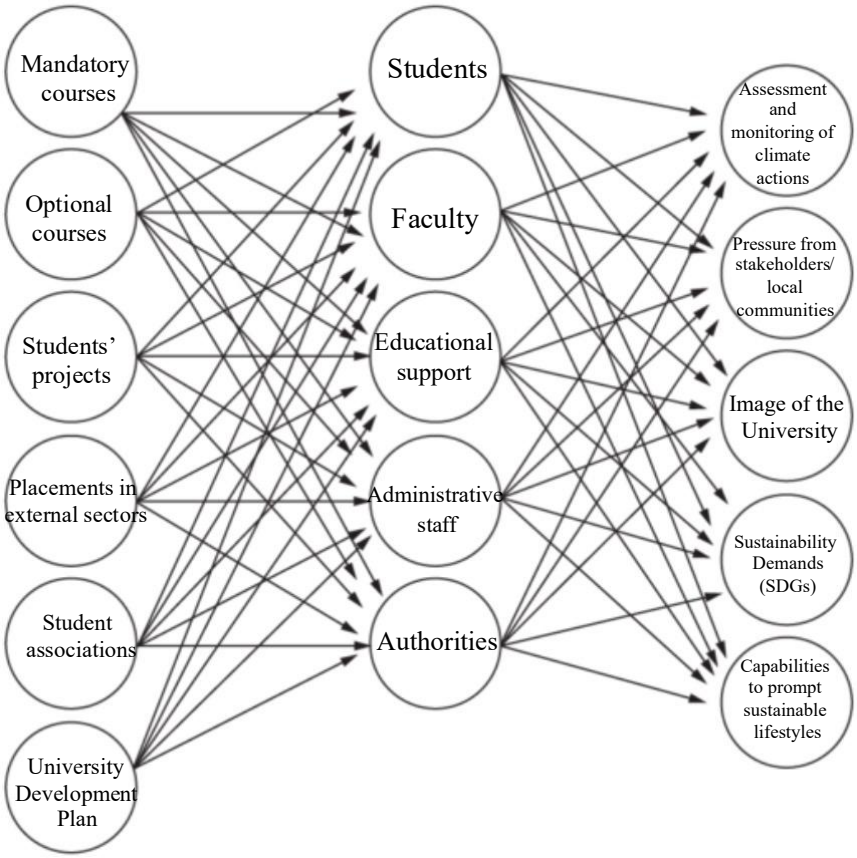
Universities have the resources –education, research, and social status- to increase climate education and change the attitudes and behavior toward the environment of young generations. Mexican universities should be more than a triple-helix actor who promotes or executes projects whose scope is limited to specific university areas. Climate action implies the adoption of a new holistic socioenvironmental ethics that can contribute to building sustainable societies committed to social equity and the protection of the environment (Pearson et al., 2021). The involvement of student communities through transversal sustainability education and formal courses in all education programs is critical to increasing the interest of students to support climate change actions and become sustainability professionals; the interdisciplinary teams could achieve better results.

A major challenge is the design of transversal educational programs for climate action. According to Sharma et al. (2020), Thelken and Jong (2020), a social approach to innovation and entrepreneurship in business and engineering schools is relevant because sustainable entrepreneurship education allows the achievement of the SDGs. Global warming, air pollution, depletion of ecosystems, and the gradual decline of biodiversity among other climate change issues are urgent "global emergencies" (Boyd et al., 2022; Coscieme et al., 2020) that require a social and ecological transition supported by the University (Álvarez et al., 2024; McCowan et al., 2021; Wamsler, 2019).

The dense description shows that the climate action must involve the whole society and go beyond some "likes" or "comments" on environmental topics on social media [a phenomenon commonly known as slacktivism (Oliver, 2022)]. Based on the analysis, climate actions are diverse and not always institutionalized because of the highly heterogeneous characteristics of the universities. According to

Hampton and Withmarsh (2023), the climate action implies a fundamental cultural change and requires individuals to become “climate citizens” who participate in climate action at several levels, by expressing opinions, voting, engaging in the proposal of environmental policies, and making choices that indicate they recognize human beings are part of ecosystems and not the center of them. Figure 2 shows the identified climate actions, the actors who contribute to defining and supporting these actions, and the drivers (e.g. pressure of stakeholders) and ends (e.g. inducing sustainable lifestyles) of the ongoing transformation of universities toward sustainability.

Figure 2
Mexican system of climate education



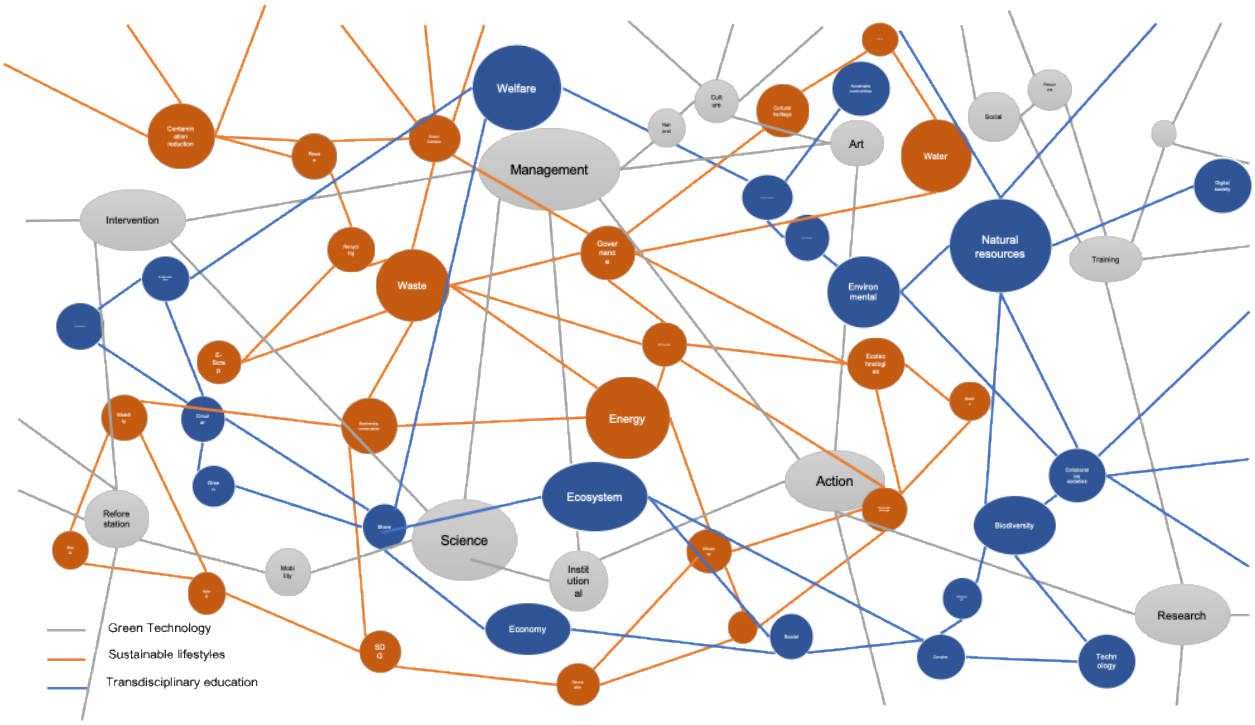
Source: by the authors.

Based on the findings, the training of communities capable of intensifying the climate actions is possible through three core functions: transdisciplinary education, promotion of sustainable lifestyles, and green-technology transfer. The three paths operate independently but they are closely interrelated because climate action involves multidirectional interactions and there is not a dominant topic or path. However, Álvarez et al. (2024) assure that the didactic models in higher education institutions should migrate from an environmental educational approach (techno-economic) to a climate education model (socioenvironmental praxis) that promotes the creation of professional interdisciplinary teams that tackle climate change problems through experiential learning and research projects conducted by several schools and with external partners.

Based on findings, Figure 3 shows a multilayer semantic network that graphically depicts how sustainable practices interconnect and are supported by interdisciplinary university communities. The network was mapped based on the co-occurrence frequencies reported in Table 4 and posits that each layer is equally relevant to the formation of communities capable of intensifying the ecosystem's actions to tackle climate change through three core functions: transdisciplinary education, promotion of sustainable lifestyles, and green technology transfer. The three layers operate independently but they are closely interrelated because the complete network involves interactions between its elements, its operation is largely based on their multidirectional interactions, and there is not a dominant topic or path.

Figure 3

The multipaths of the sustainability education



Source: by the authors.

The practical implications focus on the transformation of higher educational institutions into "sustainable universities" that educate and engage students, faculty, and communities in sustainable activities that respond to the current needs of their socio-ecological context, for example, conserving water or preventing land degradation through ecological agricultural practices. Additionally, universities must systematize their collaborative action for sustainability because networking is fundamental to providing practical solutions to the complex problems posed by climate change. These implications set the basis for the following recommendations: 1) sustainable education should begin at the basic educational levels; 2) all educational programs must integrate at least a course related to climate action; 3) the courses should be designed under an interdisciplinary approach and offered early in the curriculum; 4) universities must assume responsibility for sustainable development in their core functions, namely research, teaching, and social influence.

Mexican universities are uniquely positioned to foster the social, cultural, and structural change to impact climate action; however, an institutional framework for sustainability is essential to systematize climate

action. Universities must overcome significant institutional challenges to transform their traditional educational approaches into innovative educational models, where sustainability and educational technology are strategic pillars for achieving experiential, practical, and community-integrated learning. Based on findings, three strategies are proposed to achieve SDG 13. 1) Curricular gaps must be closed; students must acquire theoretical knowledge and develop the necessary technical and practical skills to apply it within their educational programs; socio-environmental and economic complexity demands new leadership and intermediation skills in the role of Mexican universities. 2) Educational innovation must be a central strategy to achieve the active student participation in climate action; moreover, the plan for the (re)training of professors should face the challenges of digital and climate transformation. 3) University infrastructure must be strengthened to operationalize climate education and the linking of university work with the productive, social and public sectors.

Conclusions

The analysis of the climate actions reported by public and private Mexican universities supports the premise that education in sustainability is crucial to mitigate and adapt to climate change. This research concluded that interdisciplinary university communities are capable to trigger climate action and support the three axes of the sustainability. However, current actions to tackle climate change are mainly downstream, which is promoted by students' teams for a short time, while institutionalized actions do not commit to the university community. Thus, a major challenge of climate action is the management of the social indifference toward climate change and the enhancement of the environmental awareness and perceived efficiency of pro-environmental actions of the university community. Transdisciplinary education and research, the encouragement of responsible consumption in all educational programs, as well as the use of technology are climate actions that require top-stream reinforcement.

This work adds to the discussion of the role of universities in contributing solutions to the sustainability challenges of the 21st century for socially disadvantaged regions with slack regulations, incipient environmental policies, and whose population suffers the consequences of climate change. The negative social impact of climate change demands universities to open and support new lines of sustainability research including the study of the effect that multi, inter, and transdisciplinary education has on the sustainability lifestyles and careers of faculty, staff, and students.

This study is not without limitations. The first one is the broad characterization of the universities' process of climate action. Climate actions could be further categorized using for example the archetypes that describe the projects and solutions that may contribute to building up a sustainable model for universities (Ritala et al., 2018). The second limitation is the limited generalization of results due to the qualitative research approach used; however, the information collected comes from a heterogeneous set of university communities selected according to their experiences in supporting sustainable research projects and backing climate actions. The replication of the study using a stratified sample of Mexican universities would allow the confirmation and extension of results. Likewise, critical analysis of international university strategies will be considered in the next phase of the research to strengthen the explanation of why some initiatives performance better than others.

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