Technology and infrastructure required by Latin-American universities for the achievement of the SDGs

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Abstract: This paper aimed to analyze the new technologies and infrastructure of Latin- American universities to support the accomplishment of the SDGs. The methodological approach was qualitative which included a systematic review of the literature and a survey of 24 Latin-American universities from six countries recruited through a snowball sampling plan. The findings indicate that the institutional investment in new technologies and infrastructure for the achievement of the SDGs is limited and the pace of progress insufficient. The scarcity of the efforts from the university community to support the SDGs, directly and indirectly, was also evident. The main conclusion is that institutionalization and coordination of (physical and human) resources are required so that universities can become active promoters of the SDGs.

Keywords: Latin-American University; Higher Education Institutions; Sustainable Development Goals (SDGs); university infrastructure and technology.

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Tecnología e infraestructura requeridas por las universidades latinoamericanas para el logro de los ODS

Resumen: el objetivo fue analizar las tecnologías e infraestructura en las universidades latinoamericanas para apoyar el logro de los ODS. El enfoque metodológico fue cualitativo; se recurrió a una revisión exhaustiva de la literatura y a una encuesta en la que participaron 24 universidades latinoamericanas de seis países, que fueron seleccionadas mediante un muestreo por bola de nieve. Los principales hallazgos fueron que la inversión institucional en nuevas tecnologías e infraestructura orientada al logro de los ODS es limitada y el grado de avance insuficiente. Los esfuerzos exiguos de la comunidad universitaria para fomentar directa e indirectamente el logro de los ODS también fueron evidentes. La principal conclusión es que las universidades requieren de la coordinación de sus recursos (físicos y humanos) para llegar a ser actores estratégicos para fomentar el logro de los ODS.

Palabras clave: universidad latinoamericana; instituciones de educación superior; Objetivos de Desarrollo Sostenible; ODS; infraestructura y tecnología universitaria.

Tecnologia e infraestrutura exigidas pelas universidades latino-americanas para o alcance dos ODS

Resumo: este artigo teve como objetivo analisar as novas tecnologias e infraestrutura das universidades latino-americanas para apoiar o cumprimento dos ODS. A abordagem metodológica foi qualitativa, que incluiu uma revisão sistemática da literatura e uma pesquisa em 24 universidades latino-americanas de seis países recrutadas através de um plano de amostragem em bola de neve. As principais descobertas foram que o investimento institucional em novas tecnologias e infraestruturas para a consecução dos ODS é limitado e o ritmo de progresso é insuficiente. A escassez de esforços da comunidade universitária para apoiar os ODS, direta e indiretamente, também ficou evidente. A principal conclusão é que é necessária a coordenação de recursos (físicos e humanos) para que as universidades possam tornar-se promotoras ativas dos ODS.

Palavras-chave: universidade latino-americana; instituições de ensino superior; Objetivos de Desenvolvimento Sustentável; ODS; infraestrutura e tecnologia universitária.

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Introduction

The 17 Sustainable Development Goals (SDG) comprising 169 targets are at the core of the 2030 agenda proposed by the UN to operationalize the social, environmental, and economic actions to support global and regional sustainable development (UN, 2015). The social demand to implement a national strategy aimed at achieving the SDGs given the economic, social, cultural, and political context has increased due to the shared concerns about ending poverty, improving health and education, reducing inequality, and supporting economic growth while confronting climate change (Leal *et al.*, 2020b; Sachs *et al.*, 2019). However,

the implementation of concrete actions to attain the SDGs continues to be a major challenge (McCowan *et al.*, 2021; Ridhosari & Rahman, 2020). Researchers have tried to understand the meaning of the SDGs and their adoption in different contexts and concluded that the 17 SDGs are indivisible, highly interactive, and require interdisciplinary efforts for their achievement. (Al-Saidi, 2021; Eisenmenger *et al.*, 2020; Leal *et al.*, 2022b; Sachs *et al.*, 2019; Salvia *et al.*, 2019)

Several reports show that the progress of the SDGs' implementation has been slow (Leal *et al.*, 2023b; Onyango & Ondiek, 2021; Xie *et al.*, 2021) and there is a high disparity in the priorities assigned to certain actions among regions (Al-Saidi, 2021; Lewis *et al.*, 2021). According to Leal *et al.* (2022a, 2022b), the main factors that explain the unsatisfactory results on the implementation of the SDGs are the economic priority over social and environmental goals, the low frequency of updating the progress towards the SDGs among various regions, and the orientation of collective holistic actions towards the symptoms but not roots of the sustainability problems. The scale, scope, and complexity of the 17 SDGs require the alliance of different sectors – government and non-governmental institutions, private companies, academic groups, civil society, and individuals- (Leal *et al.*, 2022b) and requires investment, technology, infrastructure, and the coordination of objectives and resources of multiple stakeholders. (Vinca *et al.*, 2020)

Universities can play a critical partnership role with both governments and businesses given their educational and research resources, and their capability to design and coordinate social interventions, (Álvarez, 2022; Leal & Vasconcelos, 2022). The extant literature shows multiple efforts and experiences of the participation of the university to communicate and support the SDGs (Sánchez-Carrillo et al., 2021; Zguir *et al.*, 2021). However, the adoption of the SDGs by universities must be accompanied by institutional commitment, learning-teaching processes that provoke the appropriation of values and socially responsible behaviors towards the environment, the community, and vulnerable sectors, and the prioritization of an action-research approach (González *et al.*, 2022). Furthermore, resource investments and new technologies are required to support the University's actions towards the achievement of the SDGs in its region of influence. (Adshead *et al.*, 2021; Chen *et al.*, 2021)

Although some studies have shown that Latin American university projects are based on principles of social justice and sustainability, their results are limited and inconsistent because of the high social heterogeneity of the communities and contexts in which universities operate (Aguinis *et al.*, 2020; Casas, 2020; Fuente *et al.*, 2019). However, recent studies have evidenced that research and technological development in Latin American universities can be change agents and support social transformation by enabling the

social upgrading of disadvantaged groups, promoting the societal impact of research, and engaging with other universities and stakeholders.

For instance, Arocena and Sutz (2021) remark that the Latin-American universities' capabilities to design and implement social interventions can help to increase the accessibility to technology towards disadvantaged groups through programs such as the 'Community Indigenous Telecommunications' implemented in Mexican rural areas of the states of Oaxaca, Guerrero, Puebla, Chiapas, and Veracruz (Martínez & Barroso, 2019), and complement institutional efforts by bringing knowledge and innovations to social inclusion projects such as improving the availability of technical aids to people with motor disabilities or the "Research and innovation oriented to social inclusion" program of Uruguay. (Arocena & Sutz 2021)

Nevertheless, universities require institutional and operational planning, additional infrastructure, and new technologies to support sustainability under a complex and restricted context (Álvarez, 2022; Arocena, 2022; Leal *et al.*, 2022a). The number of studies about how universities can align their efforts to support sustainability actions in heterogeneous and socially disadvantaged regions such as Latin America is limited. To fill this gap and based on the assumption that the university plays a strategic role in the achievement of the SDGs, this study aims to answer the following research questions: 1) What are the current and potential technology and infrastructure resources of Latin American universities to support the achievement of the SDGs and 2) how universities align their actions and research projects to more actively participate in the solution of social and environmental problems?

Theoretical framework

Quality of education, excellent research, and recently social responsibility (SR) have become important aspects of universities' responsibility and legitimacy. The institutional environment has exerted strong social pressure –coercive, normative, and mimetic- to increase the universities' SR and their engagement with public and private organizations to respond to global challenges (Godonoga & Sporn, 2023). According to DiMaggio and Powell (1983), organizational change is caused by institutional pressures at the micro or macro level and facilitated (or inhibited) by the organization's interests, power structures, values, ideas, and beliefs. (DiMaggio & Powell, 1983; Zucker, 1987)

Despite isomorphism structure and being subject to the same institutional pressure, some organizations have responded through strategic or operative changes to support sustainability and others have not. For instance, at the micro level (endogenous approach), some universities have adopted the SDGs as a fundamental axis of their labor due to the pressure of other university communities to make organizational changes in favor of sustainability. Leadership at all levels and internal and external partnerships seem to be key

requirements to accelerate the delivery of SDGs but each university embraces its sustainable strategy according to its context and external influences. (Purcell *et al.*, 2019)

Concerning leadership, Leal *et al.* (2020a) view universities as sustainable leaders that can induce future professionals and faculty to become aware and adept at SDGs and support social marketing programs aimed at adopting sustainable behaviors. Internally, the university requires leadership for sustainability, expressed as a combination of different leadership approaches to guide the community (university employees and students) to engage in sustainable actions (e.g., use a more sustainable transportation mode or learn/implement circular business models), manage complexity, get funding, and create/reinforce interdisciplinary connectedness. Sustainable leadership can take different forms, from a formal Sustainability Office to a group of students, but it requires the support of senior management and proper governance. Functional leadership and governance are crucial to creating enablers of sustainability, overcoming barriers, designing and implementing sustainability strategy plans, developing a sustainability culture, and inserting the university into regional networks. (Leal *et al.*, 2023a)

Regarding university partnerships, a variety of characteristics, factors, and conditions that upgrade collaborative outcomes, have been examined mainly from inter-organizational and innovation-oriented perspectives (Álvarez, 2022; Olsson *et al.*, 2021; Wang & Lu, 2021). The transaction cost theory explains that the exchange of complementary or similar knowledge between organizations has individual and collaborative effects that increase the absorptive capacity and reduce collaboration costs (Cohen & Levinthal, 1990). Meanwhile, the organizational learning theory explains that inter-organizational collaboration generates opportunities for mutual learning which in turn increases the chances of positive outcomes (Alireza *et al.*, 2022). Furthermore, the resource dependence theory explains that the actors in a certain region do not survive in isolation but rather depend on their linkages to mitigate their limitations and improve their innovative capability to solve problems (Pfeffer & Salancik, 2003). Collaboration allows the development of capabilities that are essential to propose solutions aimed at achieving the SDGs. (Vazquez-Brust *et al.*, 2020)

The insertion of the university into collaborative networks is effective when technical knowledge is (re)combined with local knowledge to collectively address sustainability issues (Álvarez, 2022). However, internal transformations are required; these transformations would imply re(thinking) and re(adjusting) values, beliefs, and goals (Masson & Fritsche, 2021; Woiwode *et al.*, 2021), as well as revising the university's organizational structure and management processes to systematize sustainability action (Leal & Vasconcelos, 2022) and facilitate collaboration with external people and organizations. (Álvarez & Palacios, 2021)

The Latin-American context demands greater interaction and dynamism from universities to drive socioenvironmental justice (Arocena, 2022; Arocena & Sutz, 2021; Casas, 2020, Fuente *et al.*, 2019). The concept of a "living lab", a dynamic network that combines the university's intellectual and other resources with practical sustainability challenges on- or off-campus results in a proper model to guide transformative institutional change and combine the activities of education, research, external engagement, and administrative practice to fulfill the SDGs. (Purcell *et al.*, 2019)

Generally, a university collaboration is bilateral when the interaction is with companies and multilateral when the interaction is with the social and public sectors (Álvarez & Palacios, 2021; Olsson *et al.*, 2021; Wang & Lu, 2021). The triple (quadruple or even quintuple) helix model has been applied to describe the multiple interactions between the university, industry, and government to get resources, and share capabilities and knowledge to foster sustainability (Álvarez, 2022). However, the operationalization of collaboration and social intervention is complex because of the high regional heterogeneity. Therefore, more studies that explore how the technology, knowledge, and scientific resources of the Latin-American universities, if properly combined with the core resources of other organizations, contribute to the building of capabilities and the co-creation of a public policy of science, technology, and innovation that advance the SDGs are recommended given the leading role universities can play to foster transformative sustainable innovation. (Villa *et al.*, 2023)

Methodology

The research was exploratory with an explanatory emphasis. The methodological approach was qualitative, and the process was integrated into two phases. The first was a systematic review of literature. The second was a survey applied in 24 universities of Latin-America –Argentina (AR), Chile (CH), Colombia (CO), El Salvador (SV), Mexico (MX) and Peru (PE)-. Data triangulation was used to support internal validation whilst the participation of universities from different countries allowed generalization, thus contributing also to external validation. (Yin, 2013)

The first phase was conducted with a deductive approach. SCOPUS and Scholar Google databases were used. The following combination of words was used to capture specific regional interest: TS= (("SDG*" OR "sustainable development goal*") AND ("implement*" OR "operational*" OR "achieve*") AND ("resource*" OR "investment*" OR "technology*" OR "infrastructure*") AND ("university" OR "universities" OR "higher education institutions") AND ("Latin America" OR "Latin-America" OR "Latin American" OR "Latin-American")). After the revision of the abstracts, a total of 142 related articles were selected, and after a skim lecture 76 works were analyzed. The information was semantically analyzed and categorized through word cloud analysis and calculation of frequencies of co-occurrence.

In the second phase, the survey was designed to expose the needs of the University in regard to technologies and infrastructure that may enable it to further sustainability culture, and to education, research, mitigation, and intersectoral connection to support the SDGs. Based on the findings of the systematic review of literature, this measure tool was integrated by 15 questions to cover five dimensions: institutional policies and strategies; projects and actions of the university community; level of involvement and commitment; perception of investment and availability of technologies and infrastructure; facilitators (inhibitors) for achieving. Besides, one open question about the university interaction and its transformative role through new technologies to accelerate the achievement of the SDGs was included.

Before the application of the survey, three experts from different disciplines gave their feedback to guarantee that the questions were clear and sensitive themes phrased impartially. The key informants in each institution were identified and the survey attached with a brief description of the project was directly submitted to them (Patton, 2014). Respondents were current sustainability managers or individuals with previous experience on the planning and implementation of sustainability initiatives launched or planned by the sustainability offices from the universities in question. The sample was conformed of 54,0% private institutions and 46,0% public institutions. Table 1 shows the institutional profile of the survey respondents by main area of knowledge and country

Table 1. Institutional profile and proportion of the sample

Country Area of knowledge	AR	CH	CO	SV	MX	PE	Sample Proportion (%)
Agricultural Sciences	-	4,2	-	-	-	4,2	8,3
Earth Sciences	-	4,2	-	-	-	-	4,2
Economic Sciences and Management	-	4,2	8,3	4,2	4,2	-	20,8
Engineering and Technology	4,2	-	4,2	-	8,3	4,2	20,8
Environmental Sciences	-	-	4,2	-	4,2	4,2	12,5
Humanities	4,2	-	-	-	-	-	4,2
Law	4,2	-	-	-	-	-	4,2
Natural Sciences	-	4,2	4,2	-	8,3	-	16,7
Social Sciences	-	4,2	-	-	-	4,2	8,3
Sample proportion (%)	12,5	20,8	20,8	4,2	25,0	16,7	

Source: by the authors.

Research findings

The research findings were discussed as follows: institutional policies and strategies; involvement and commitment to sustainability; actions of the university community aimed to promote/support sustainability development, focused on technology and scientific projects; perceived investment and availability of technologies and infrastructure backing the SDGs; facilitators (inhibitors) to achieve the SDGs mainly through the adoption of green technologies.

Institutional Policies and Strategies

The key participation of the university was highlighted in terms of its role as a "shock absorber" actor that generates interdisciplinary knowledge and new technologies that can be transferred via collaboration with private and governmental institutions, and it is an entity without economic or political interests that makes it an impartial mediator. Research and technological innovation should be based on the needs of public and private organizations and society in general to ensure funding. This finding agrees with Arocena and Sutz (2021) who highlight the university innovation potential in Latin America even under scarcity. Public-private-academic partnerships were cited as a feasible solution for the acquisition of the specialized and expensive infrastructure required to strengthen research and technological development oriented to the attainment of the SDGs, given the limited funds of universities that suffice only to cover operational costs.

Research in social sciences was advised to be interdisciplinary and aimed to support the design of social marketing programs and public policies focused on the reduction of inequalities –cultural, gender, access to technology, clean water, and food-. The social, cultural, scientific, and economic ties of the University with its community were acknowledged as beneficial to propose interventions and projects that contribute to the solution of local problems. A cited example was a project regarding the design of a Bike Sharing System in collaboration with the municipal authorities that consider the needs and travel patterns of the inhabitants of large Mexican cities. However, greater collaborations with international, national, and local entities were advised to promote the design and implementation of educational programs that increase environmental awareness and concerns of the local community and to develop research that addresses the major problems summarized by the SDGs.

Findings also show that universities are expected to support a strategy to improve the digital skills of technology developers in different areas such as healthcare and reduce the digital gap among users. The need for infrastructure and education in Information and Communication Technologies (ICT) was identified as necessary to support SDG9, SDG10, and SDG11. Some collaborative projects such as the improvement of public transportation systems, related to SDG-11, were cited. The relevance of ICT in pursuing the

SDGs has been pointed out by authors such as Vinuesa *et al.* (2020) and Wu *et al.* (2018) who discuss the potential of digital technology as an enabler or inhibitor of the SDGs. Besides, participants declare a strong agreement on the necessity to work on joint projects and establish alliances with the public sector to reduce the digital gap. Table 2 summarizes the strategic lines of research, technology, and scientific projects that universities can pursue to advance the SDGs.

Table 2. University infrastructure and its possibilities
for technological development

Infrastructure	Lines of research and technological development	Impacted SDGs
Interdisciplinary laboratories	Food production.	Poverty (1), Zero Hunger (2), and Food Security (3).
Interconnected Technology Laboratories	Water, energy, and waste management. Transport and communication systems (Low carbon approach). Pollution control.	Affordable Clean Energy (7), Clean Water and Sanitation (6), Climate Action (13) and Health (3).
Social laboratories	Formal and informal education systems.	Poverty (1) and gender (5).

Source: by the authors.

A common concern from all participant Latin-American universities was the need to elaborate and distribute periodic reports regarding the sustainability actions and the assessment of their impacts, for instance, the record of the percentage of use of renewable energy in their facilities, and the tracking of their advancement towards sustainability. The development of technologies for measuring the socioenvironmental impact of the different actions has a high priority that goes beyond the report of percentages of substitution of non-renewable energies, the number of collected recyclables, or the number of research projects about socially disadvantaged groups. Therefore, the measurement of the contribution of the actions of universities and any other organization on the attainment of the SDGs requires technological and social innovation.

Contribution and commitment of universities to sustainability

The case analysis showed a consensus that universities should play a more active role in the achievement of the SDGs, beyond their compromise with targets, 4.3 (equal access to higher education) and 4.b (scholarship) of SDG4. Thus, universities are expected to adapt their teaching and learning content to the SDGs and commit more resources to sustainability projects. SDG4 was considered indirectly related to other SDGs (1, 3, 5, 7, 9, 12, 16, and 17) because the promotion of R&D, the development of human resources with a deep understanding of sustainability, the advancement to an inclusive

society, and the capacity to collaborate with organizations from other sectors add to the solution of critical socioeconomic and environmental problems.

These findings agree with the concept of Education for Sustainable Development proposed by Ashida (2023), which refers to an educational approach that "fosters the ability to view diverse issues such as poverty, human rights, development, and the environment as one's own problems and to take independent action in solving them". The concept also acknowledges the need to disseminate and apply technology and scientific discoveries to understand and solve the global problems addressed by the SDGs. Moreover, participants agree that the leading role of the University depends on its insertion into the social, institutional, financial, and political complex networks related to the SDGs. Figure 1 shows the perceptions of the respondents regarding the SDGs priorities of their universities. The horizontal axis corresponds to the median level of importance assigned to each SDG, the higher the value, the greater the importance of the SDG.

Figure 1. Perception of SDGs' relevance to participant universities
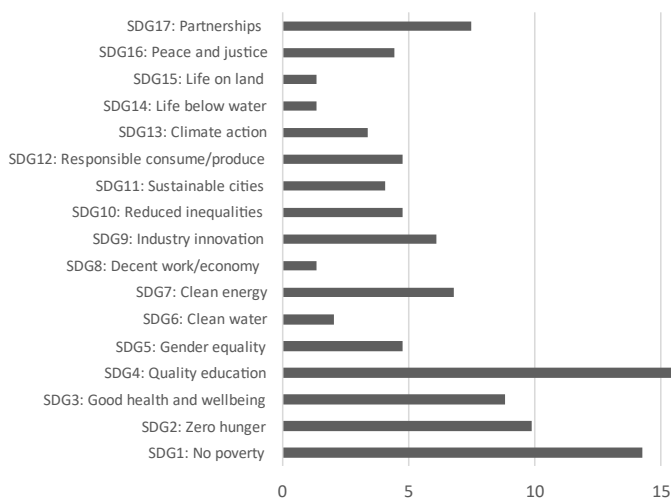
Source: by the authors.

Based on the previous graph, social issues seem to be the main concern of universities, meanwhile, environmental themes are judged to be problems that universities have less capabilities and physical infrastructure to attend to. The interdisciplinary collaboration with social impact was qualified as critical. Results agree with the bibliometric analysis because the contribution of social sciences and engineering to social welfare and sustainable innovation has been recognized. (Bain *et al.*, 2019; Fritz *et al.*, 2019; Alcamo *et al.*, 2020; Wang *et al.*, 2020; Gyasi *et al.*, 2021)

Projects and Actions of the University Community

Table 3 shows the priority issues identified in the bibliometric analysis complemented with the case analysis information. The projects and actions are mainly focused on the technologies and infrastructure to be internally developed or externally acquired to support the SDGs; other actions such as the design of social interventions are not out of the scope of the analysis.

Table 3. Priority issues, base technologies, and infrastructure identified to support SDGs

Priority	Main trends	Proposed investments
Food safety (SDG 1, 2, 3, 11, 12, 13)	• Healthy and sustainable food systems. • Responsible consumption. • Recovery of regional knowledge and best practices of indigenous communities.	Technologies for food processing, inspection, verification, and certification in the supply chain. Technologies for Smart Agriculture such as wireless sensor networks in farming, monitoring irrigation valves and switches operation, and remote area control. Legislation and technological infrastructure to scale the promising results. Research projects in innovative education from the perspective of the SDGs. Support for the university culture oriented to sustainability.
Energy transformation (SDG 1, 3, 7, 14 y 15)	• Alternative systems for power generation. • Systems for measuring the environmental impact of "green" technologies. • Energy-efficient urban mobility (electromobility) systems. • Responsible consumption to lower energy demand.	Development and use of clean and renewable energy resources such as wind power, solar, and geothermal. Infrastructure in scientific laboratories to improve the measurement of emissions and to save energy and water. Legislative and social infrastructure to protect natural ecosystems and regulate the generation of "green" energy. Support for the university culture oriented to sustainability.
Health (SDG 3, 6, 10, 12, 14, 15)	• Artificial intelligence systems to prevent breast cancer. • Bioengineering to avoid diabetic foot amputation and blindness. • Prevention and health care systems. • Platforms to promote digital transformation in healthcare.	Big data analytics. Technologies related to early diagnosis of cancer and diabetes. Research on antibiotic resistance, viral outbreaks, and biomedical devices such as infusion pumps, heart-lung machine, dialysis machines, artificial organs, implants, and artificial limbs. Technological infrastructure in research and social laboratories for the adoption of technology with a responsible approach.

Source: by the authors.

These findings agree with studies that acknowledge as critical the protection of agriculture and food systems (Zhou *et al.*, 2021), the management of water and energy (Reimer *et al.*, 2020), and the digital transformation of health care (Mozas *et al.*, 2020). Moreover, emphasis was placed on the urgency of promoting a culture of sustainability in the university by initiating a communication campaign throughout all university channels to inform about the university's actions driven by the SDGs and track its progress. This proposal agrees with Djekic *et al.* (2019), who conclude that the individual is the base unit for changing behaviors, especially those related to food waste.

The proposal to reinforce the educational programs in engineering and technology in sustainable food, circular economy, biofuel development, and biomedicine, among others was also frequently cited as a strategy that would support the SDGs through education, research, and collaboration. The need for a framework that guides the systematic introduction of the SDGs in educative programs of institutions of higher education has been acknowledged by authors such as Leal *et al.* (2021). Furthermore, the pressure to expand sustainability education at all levels has continuously increased. (Leal & Vasconcelos, 2022; Chen *et al.*, 2021)

The literature review showed the need to define an energy research agenda with a focus on "environmental justice" that ensures the mitigation of the environmental impact of the use of non-renewable energy and the reduction of its negative effects on ecosystems and health (Werner & Benites, 2023). The case studies analysis indicates that universities can play a key role by increasing environmental awareness, promoting a sustainable energy culture through the regional diffusion of scientific projects, and applying the knowledge of native eco-friendly communities combined with technical knowledge to support sustainability. The energy transition was cited as one of the priorities for university research; however, universities recognize that Latin America is one of the least prepared regions to accomplish this transition due to the low availability of resources, inadequate public policies, and geopolitical energy disputes. (Serrani & Santos, 2021)

Technology and infrastructure backing the SDGs

In general, the investment of the universities in new technologies and infrastructure to fulfill the SDGs is limited. The progress towards sustainability is very slow and the importance assigned to the indicators comprising the SDGs, for instance, the reduction of the carbon footprint beyond regulations, is low. This is consistent with the literature review that indicates that access to sustainable technologies among universities has been unequal because of the high acquisition costs (Álvarez, 2022; Escobar & Laibach, 2021; Leal *et al.*, 2022b). For instance, a private lead Mexican university reports the installation of photovoltaic panels in its main campuses, the replacement of air conditioning units for high-efficiency units plus the installation of 168 smart thermostats to improve the use of air conditioning systems.

This university has also invested in a hydro-sustainable building that captures and filters rainwater to satisfy a proportion of the internal needs and is almost totally disconnected from the city's water network. In contrast, public universities in the same country have problems even with the installation of LED fluorescent lighting and their pro-environmental actions are limited to the implementation of recycling programs of PET and paper that is recuperated by private companies as part of their green programs. Despite the limited global investment in physical resources (for instance, biotechnology laboratories) and research projects with a socioenvironmental focus, universities have reported several technological developments mostly at the "pilot" level but with the potential to support SDG-6 (clean water and sanitation) and SDG-7 (affordable and clean energy). Among them, there is a technology that removes arsenic from water, converts waste to energy, and generates bio-based energy. (AlQattan *et al.*, 2018; Escobar & Laibach, 2021; Ersan *et al.*, 2023)

## Facilitators and inhibitors for the achievement of SDGs

The analysis of the case studies indicates that the participant Latin-American universities perceive large barriers to support the achievement of the SDGs. In general, respondents agree the immediate university's contributions are to ensure inclusive quality education (SDG-4), contribute to peace, justice, and gender equality (SDGs 7 and 8), and encourage responsible consumption (SDG12) through the promotion of sustainability culture and educational programs because these actions do not represent a large financial investment. For instance, the Internet and media-rich web applications that most of the participant universities implemented during the pandemic were cited as technologies that facilitate access to quality education for more segments of the population. Respondents also agree that if the institution authorities launch a sustainability action strategy, prioritize and push the use of technologies generated by the university community (e.g., biodegradable plates, straws, and cutlery made of 60% with bioplastics manufactured from avocado seeds), and utilize their available human/knowledge resources and infrastructure (e.g., laboratories) it would be possible to consolidate more sustainability research projects and actions.

Based on the previous findings, the university approach towards the SDGs requires a two-way transformation: 1) top-down because it is indispensable to design an organizational strategy that consolidates the efforts of the university community and commit resources to improve the infrastructure and develop/acquire green technologies, and 2) bottom-up because the compromise from all university associates (faculty, students, managers, and authorities) is necessary to lessen socioenvironmental indifference. Important actions are the introduction of sustainability topics in the curriculum of all schools and the promotion of research and consulting projects to attract funds with a clear social and environmental impact.

The experience in organized activities is relevant to the promotion of the civic and social responsibility of the community, the development of environmental consciousness, and the design of a curriculum that promotes critical thinking and enables innovative learning (Ashida, 2023; Leal *et al.*, 2023a; González *et al.*, 2022). Therefore, the achievement of the SDGs by universities requires pedagogical planning for learning, service, participation, skills, values, networking, professionalization, coordination, and monitoring. Figure 2 shows the fundamental lines of action

universities can implement to engage with the SDGs through their key activities of education, research, and provision of continuous training and consulting to external organizations and communities.

Figure 2. University action to foster the achievement of the SDGs
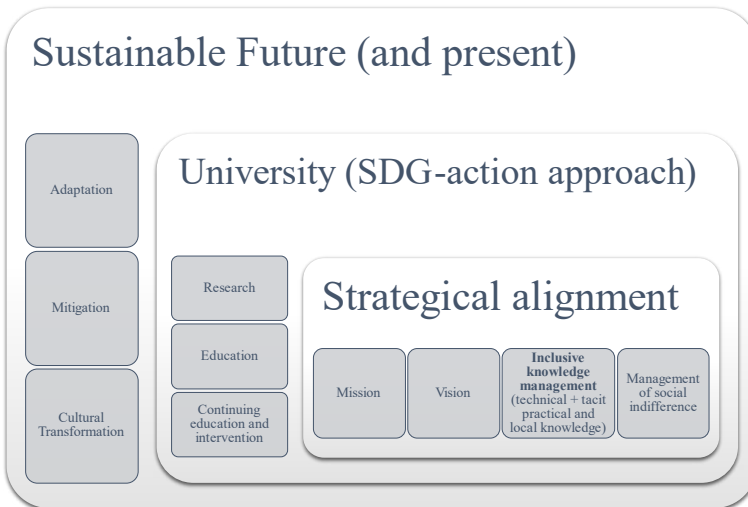
Source: by the authors.

Conclusions

The contribution of Latin American universities to the achievement of the SDGs is highly heterogeneous due to the socioeconomic context and limited resources of universities. Top management leadership and priorities, along with the socioenvironmental context such as productive orientation, natural resources, and social inequalities exert pressure on universities to adopt sustainability practices. Moreover, the values and beliefs of the university and its surrounding community influence the balance of the economic, educative, social, and environmental goals of universities, and shape their intervention and research action. Also, the power structures affect the networking and leadership role of the university to support the SDGs.

Latin-American universities, with their unique social position as generators and sources of knowledge, can play a critical role in the achievement of the SDGs. However, the university needs to institutionalize and merge the isolated efforts of its community to address the challenges of the SDGs' targets in collaboration with public, private, and civil organizations. The integration and implementation of the SDGs within the university's strategy, policies, and actions require the leadership of top authorities who also need to assign current resources and obtain additional funds to integrate education, research, and relationships with industry to identify and propose solutions to problems related to the SDGs'. Partnerships and cooperation with local private and public organizations, non-governmental agencies, and civil society must be part of the global strategy to accelerate action on the SDGs along with investments in human and physical resources, the adoption of technology, and the reinforcement of the university infrastructure.

The capabilities of the university community are the strategic source to generate science technology and innovation, and the formation of human resources with sustainability competencies and orientation that can support the SDGs is the key. However, the institutionalization and coordination of (physical, human, and knowledge) resources are required so that universities can become active promoters of the SDGs. The social disadvantage that prevails in the Latin American region could trigger innovation and strengthen the social orientation of universities. Therefore, it is proposed that the continuous interaction of the university with its community problems is essential for a significant learning oriented to the solution of social and environmental problems in despite of the tight available resources that universities have.

The case analysis methodology utilized in this work prevents the generalization of the results, however, the profile of the units of analysis assures the representativeness of universities with different profiles that operate in contexts with different levels of disadvantage. Future research includes performing a quantitative study on a representative sample of universities stratified by country. This research has practical implications for policymakers who are encouraged to include local universities in projects and networks aimed at supporting sustainable development. The participation of universities in such networks can contribute to strengthening the dynamical capabilities of the participants and to visualize sustainability problems from a boarder perspective. Furthermore, another venue of research is to explain the formation and progress of inter-university and multi-sectorial networks as complex systems motivated by socio-environmental responsibility. Finally, another research project derived from this work is measuring the impact that research, technology development, and innovation have on the solution of regional sustainability problems.

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