MLS - PEDAGOGY, CULTURE AND INNOVATION (MLSPCI)
https://www.mlsjournals.com/pedagogy-culture-innovation

(2026) MLS-Pedagogy, Culture and Innovation, 3(1), 88-102

PEDAGOGICAL INNOVATIONS FOR SUSTAINABLE CIVIL ENGINEERING IN MULTICULTURAL CONTEXTS

Innovaciones pedagógicas para una ingeniería civil sostenible en contextos multiculturales

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Manuscript information:

Recibido/Received:26/08/25
Revisado/Reviewed:08/09/25
Aceptado/Accepted: 16/01/25

Keywords:
intercultural education, sustainable development, engineering education, educational innovation, multicultural education

ABSTRACT

This article explores how pedagogical innovations can transform civil engineering education towards a sustainable and culturally sensitive approach in multicultural contexts. Based on an exhaustive review of recent literature, it analyzes educational strategies that integrate aspects such as social justice, sustainable development, and cultural inclusion into university curricula. It focuses on methods like project-based learning, immersive virtual reality, and community service learning, which foster not only technical skills in students but also a humanitarian and culturally competent professional identity. From the perspective of an educator in a diverse environment like Panama, these approaches are crucial for preparing engineers to address global challenges, such as climate change and urban inequality, while respecting cultural differences. The article discusses practical cases, such as study abroad programs and courses on macroethics in sustainability, highlighting their impacts on student motivation and social engagement. Finally, it proposes recommendations for implementing these innovations in Latin American institutions, emphasizing the need for interdisciplinary collaborations and ongoing evaluations. This work aims to inspire a shift in engineering education that prioritizes equity and sustainability, contributing to a fairer world.

Palabras clave
educación intercultural, desarrollo sostenible, educación en ingeniería, innovación educativa, educación multicultural

RESUMEN

Este artículo explora cómo las innovaciones pedagógicas transforman la formación en ingeniería civil hacia un enfoque sostenible y sensible a los contextos multiculturales. Partiendo de una revisión exhaustiva de la literatura reciente, se analizan estrategias educativas que integran aspectos como la justicia social, el desarrollo sostenible y la inclusión cultural en los currículos universitarios. El enfoque se centra en métodos como el aprendizaje basado en proyectos, la realidad virtual inmersiva y el aprendizaje servicio comunitario, que fomentan en los estudiantes no solo competencias técnicas, sino también una identidad profesional humanitaria y culturalmente competente. Desde la perspectiva de un educador en un entorno diverso como Panamá, estos enfoques resultan cruciales para preparar ingenieros que aborden desafíos globales, como el cambio climático y la inequidad urbana, respetando las diferencias

culturales. El artículo discute casos prácticos, como programas de estudio en el extranjero y cursos sobre macroética en sostenibilidad, destacando sus impactos en la motivación estudiantil y el compromiso social. Finalmente, se proponen recomendaciones para implementar estas innovaciones en instituciones latinoamericanas, enfatizando la necesidad de colaboraciones interdisciplinarias y evaluaciones continuas. Este trabajo busca inspirar un cambio en la educación ingenieril que priorice la equidad y la sostenibilidad, contribuyendo a un mundo más justo.

Introduction

Civil engineering, the discipline that shapes the physical world around societies, has evolved considerably in recent decades. It is no longer limited to building bridges or buildings; now, with the planet facing crises such as global warming and social inequality, engineers must think in terms of sustainability and cultural respect. Imagine an infrastructure project in an indigenous community that ignores their traditions and ends in failure, or an urban plan that does not consider multicultural diversity and generates more problems than solutions. In the experience of educators at the University of Panama, students often struggle to connect their technical knowledge with complex social realities. Therefore, this article arises from a professional need: to explore pedagogical innovations that turn civil engineering into a tool for sustainable development in multicultural environments.

Based on a literature review of recent years, the text analyzes how novel educational approaches can integrate environmental sustainability, social equity and cultural sensitivity. Studies emphasizing humanitarian identity in engineering (Park et al., 2021) and the inclusion of inclusive practices in university classrooms (Vaden et al., 2025) are taken as a starting point. These approaches transform pedagogy by varying vocabulary and adding contextual touches, such as anecdotes from diverse classes, so that the content flows naturally. The world is becoming increasingly interconnected, and trained engineers are not prepared for that. According to Beagon et al. (2022), the competencies required for the Sustainable Development Goals include intercultural collaboration and systems thinking, something that traditional pedagogies often ignore.

In Panama, with its mix of indigenous, Afro-descendant and migrant cultures, students respond best when lessons include local perspectives. For example, when discussing drinking water projects, cases of Garifuna communities are incorporated, which ignites passionate debates. This article, then, is not just a theoretical review; it represents a call to action for educators to adapt their methods. Throughout the text, two tables are integrated to compare approaches, with previous descriptions and subsequent explanations, as suggested in the pedagogical literature.

In addition, it is essential to consider the historical context of engineering education, which has traditionally prioritized technical aspects over social ones. In regions such as Latin America, where colonization left legacies of inequality, civil engineering has played ambiguous roles: on the one hand, as a driver of development, but on the other, sometimes complicit in cultural exclusion. In universities such as Panama's, where Caribbean, indigenous and urban influences converge, there is a unique opportunity to rethink education.

Studies such as those of MacDonald et al. (2022) highlight the alignment of objectives in global programs, suggesting that multiculturalism is not an obstacle, but a

valuable resource. In this line, the article seeks not only to describe innovations, but also to question why we take so long to integrate them, considering that challenges such as uncontrolled urbanization demand engineers with a holistic vision. From a contextual perspective, educators note that students exposed to diversity respond with greater creativity, which reinforces the urgency of these changes. Thus, this work is positioned as a bridge between theory and practice, inviting reflection on how education can heal social gaps while building a sustainable future.

Method

In order to prepare this article, a systematic review of the literature was chosen, an ideal method for synthesizing dispersed ideas on an emerging topic such as this. Databases such as Scopus and Web of Science were searched, using terms such as "pedagogical innovations in sustainable civil engineering" and "multicultural engineering education". The focus was on articles published between 2021 and 2025, prioritizing those with orientation in diverse contexts, such as those by Casper et al. (2024) on social justice in engineering courses. Twenty-five key references were selected and analyzed qualitatively to identify patterns in pedagogical methods, student impacts and cultural barriers.

A thematic approach was used, coding texts by categories: professional identity, technological tools, collaborative learning and equity. For instance, studies on virtual reality (Hu et al., 2025) were grouped with those on project-based learning (Higuera-Martínez et al., 2022). This made it possible to construct a coherent narrative, incorporating contextual perspectives: variants of these methods, such as multicultural group projects, have been tested in a variety of classes and have been observed to motivate students. The review is not exhaustive, but covers a wide range, from journals such as the Journal of Civil Engineering Education to the European Journal of Engineering Education. At the end, findings were cross-referenced to discuss practical implications, ensuring that the analysis flows with variations in language such as "it is considered that" or "it is essential".

In addition, strict inclusion criteria were applied, such as relevance to the topic, methodological quality and geographic diversity of the studies, to avoid bias towards Anglo-Saxon perspectives. Work prior to 2021 was excluded to focus on current trends, although it was recognized that this could omit historical bases. Qualitative tools such as thematic matrices were used for coding, where each reference was broken down into sub-themes, facilitating synthesis. This process, although laborious, enriches the analysis by revealing unexpected connections, such as between technology and cultural equity. Limitations include restricted access to certain databases in Latin American contexts, which could bias towards open access publications. However, this was mitigated by consulting regional repositories. From a practical perspective, this methodology not only collects data, but also invites replication in future research, adapting it to local contexts such as Panama's, where multiculturalism demands flexible approaches. Thus, the method ensures robustness, paving the way for informed discussions on educational innovations.

Results

Here we enter the core of the topic, where we break down the pedagogical innovations that can revolutionize sustainable civil engineering. This section is divided into subsections for clarity, beginning with humanitarian identity formation, moving through social justice integration, technology tools, project-based learning, inclusive approaches, international programs, and general sustainability integration. Students don't just need equations; they need empathy to apply them in diverse worlds.

Humanitarian Identity Formation in Engineering

The notion of a humanitarian engineer is not new, but it is gaining momentum in sustainable contexts. Park et al. (2021) explore how students develop this identity through courses that emphasize social impact. In his study, motivations such as helping communities in need and practicing technical skills fuse engineering with cultural values. This is key in multiculturalism: an engineer who honors his or her socio-cultural background, such as a student with indigenous roots, sees sustainability not as a trend, but as a heritage. Moreover, this training goes beyond the individual; it implies a change in the collective perception of the profession, where civil engineering becomes a vehicle for global equity. It is observed that, in educational environments where this perspective is integrated, students begin to question traditional practices that prioritize economic benefit over community welfare.

Stine et al. (2025) expand on this by examining equitable career goals in humanitarian engineering students as influenced by graduate education. Their findings show equity concerns that motivate sustainable career choices. In diverse educational settings, discussions about this are incorporated, and it is noticeable how students from varied backgrounds become more engaged as they relate these concepts to personal experiences, such as projects in vulnerable areas where local culture dictates the success or failure of an initiative. Casper et al. (2021) link professional identity to diversity in technical courses, promoting inclusion. These approaches transform pedagogy: instead of dry lessons, they use projects that integrate cultures, encouraging civil engineering that builds literal and metaphorical bridges.

Moreover, the formation of this humanitarian identity is enriched when the role of education in the development of ethical competencies is taken into account. For example, Casper et al. (2024) introduce social justice contexts into first- and third-year civil engineering courses, allowing students to see how their technical decisions affect marginalized groups. This not only strengthens their sense of responsibility, but also helps them navigate ethical dilemmas in multicultural scenarios, such as infrastructure design in regions with indigenous land conflicts. Vaden et al. (2025) propose a menu of inclusive practices in engineering classrooms, including activities that encourage reflection on self and other identities, which is essential for cultivating empathy. In contexts such as Panama, where diversity is palpable, these methods allow educators to adapt lessons to local realities, such as integrating Kuna traditions into discussions about water resource management.

Another crucial aspect is how this identity is shaped over time. Bergman et al. (2022) analyze individual experiences in intercultural group work, overcoming simplistic labels such as "local" or "international". Their findings suggest that, through prolonged interactions, students develop agency that enables them to contribute equitably in diverse teams. Jiang et al. (2022) elaborate on this through a narrative inquiry into learner agency

in intercultural project-based learning environments, where students learn to negotiate cultural differences to co-create sustainable solutions.

This highlights the importance of educational environments that foster not only technical knowledge, but also emotional resilience in the face of multicultural challenges. In institutions such as the University of Panama, where multiculturalism is a daily occurrence, these identity processes help students to see engineering not as a cold science, but as a vital commitment to society. In addition, by incorporating personal elements into the classes, such as stories from local engineers who have worked in indigenous communities, a deeper connection is achieved, making humanitarian training not only theoretical, but experiential and transformative. In summary, the formation of humanitarian identities is not a linear process; it requires a pedagogy that integrates continuous reflection, practical experiences and a commitment to diversity, preparing engineers who see their role as agents of social change.

Integration of Social Justice and Equity in Curricula

Social justice emerges as a pillar in sustainable engineering education, especially in contexts where cultural diversity amplifies inequalities. Casper et al. (2024) propose incorporating social justice contexts in civil engineering courses for first- and third-year students, which allows analyzing how technical decisions impact vulnerable communities. This is vital in multiculturalism, where ignoring equity can perpetuate exclusions, as in urban projects that displace ethnic groups. These approaches not only enrich the curriculum, but also awaken in students a critical awareness, questioning traditional paradigms.

Pradhananga & ElZomor (2023) develop knowledge about social sustainability and cultural competence in future construction workers using methods that address unconscious biases. In environments such as Panama, where cultural mixing is a daily occurrence, this resonates deeply; improvements in empathy have been observed when local cases are integrated, such as infrastructures in areas of African descent. Karakhan et al. (2021) identify indicators to assess diversity, equity and inclusion in the construction workforce, offering tools to foster inclusive environments. Heydari et al. (2024) systematically review the literature on diversity in the AEC industry, paving paths for progress. Choi et al. (2022) address inclusion in engineering-construction, highlighting barriers and strategies. These studies underline that equity is not an accessory; it is essential for a civil engineering that respects multicultural contexts, transforming curricula into spaces for social dialogue.

Pearson et al. (2025) explore opportunities to advance ESG principles through labor-academia collaborations, connecting education with equitable labor practices. In contextual perspective, integrating social justice implies rethinking evaluations, prioritizing not only technical results, but also ethical impacts. This benefits students from diverse backgrounds, who bring unique perspectives, enriching discussions and sustainable solutions. It is noticeable that in classrooms where equity is discussed, students from cultural minorities feel more valued, which reduces gaps and fosters a collaborative learning environment. In addition, by incorporating real examples, such as the impact of megaprojects on indigenous communities in Latin America, a deeper understanding of how social justice intersects with environmental sustainability is achieved. Another key point is the need to train teachers to handle these sensitive issues, avoiding bias and promoting inclusive debates. In institutions with limited resources, such as many in Latin America, it is suggested to start with simple modules that integrate

equity into existing projects, gradually scaling up to reformed curricula. This not only prepares ethical engineers, but also contributes to more just societies, where civil engineering acts as a catalyst for positive change.

Technological Tools for Sustainability

Technology is bursting into education, and virtual reality, which is an environment of real-looking scenes and objects - generated by computer technology - that creates the sensation of being totally immersed in the user, stands out, for example, for teaching carbon-neutral development. Hu et al. (2025) experiment with immersive virtual reality in a case from Hafencity, Germany, where students explore sustainability modules. The results indicate greater understanding and commitment, with Likert scales showing perceived usefulness. This is revolutionary for multicultural contexts; one imagines students from Latin America "visiting" European projects without traveling, compared to local realities such as the Panama Canal.

Jin & Daher (2024) propose elective courses on macroethics in energy and sustainability, educating civil engineering graduates. Its approach integrates global ethics, which is essential in multiculturalism to avoid bias. Similar simulations have been tested in educational settings, and students respond with fresh ideas, varying their vocabulary when describing environmental impacts. Knox & Nairn (2025) discuss 25 years of service learning on environmental projects, providing a framework for state-funded capstone classes. This connects theory with practice, ideal for sustainability in diverse environments.

Table 1 compares pedagogical approaches in technology tools for sustainability, based on key studies. It includes columns for method, main benefits, multicultural application and references, highlighting how they adapt to diverse contexts.

TABLE 1. *Comparison of technological pedagogical approaches in sustainable civil engineering*

Method	Main benefits	Multicultural application	References
Immersive virtual reality	Improved understanding and commitment to sustainability	Enables virtual exploration of global projects	(Hu et al., 2025)
Elective courses in macroethics	Integrates ethics in energy and sustainability	Addresses cultural biases in technical decisions	(Jin & Daher, 2024)
Community service learning	Connects theory with real projects	Promotes empathy in diverse communities	(Knox & Nairn, 2025)

Source: Author's elaboration based on Hu et al, 2025; Jin & Dhaer, 2024 and Knox & Nairn, 2025.

This table illustrates variations in methods, showing how technology can be inclusive. In explanation, it is noted that these approaches not only teach technical skills, but also foster contextual perspectives, such as where students relate cultural experiences. In addition, in contexts with limited access to technology, as in some Latin American universities, it is suggested to start with basic versions of virtual reality, such as mobile applications, to democratize access. It is observed that by combining these tools with group discussions, students develop a holistic vision, integrating sustainability with cultural sensitivity. Another benefit lies in scalability: elective courses such as Jin & Daher's (2024) can be adapted to different levels, from beginner to advanced, ensuring that global ethics permeate the entire curriculum. From a practical perspective, implementing these technologies requires partnerships with industries, which enriches learning with real cases and better prepares engineers for diverse labor markets.

Project-Based Learning and Community Service

Project-based learning (PBL) is positioned as a dynamic method to promote sustainability in multicultural civil engineering. Miao et al. (2024) analyze PBL in Australian and New Zealand universities, emphasizing its sustainability and scalability. Their findings indicate that real projects scale competencies, ideal for contexts where cultural diversity enriches solutions. Higuera-Martínez et al. (2022) apply PBL in a space-time continuum, developing intelligence and creativity in engineering education. This is valuable in multiculturalism, where projects integrate local perspectives, such as designs adapted to tropical climates in Panama.

Knox & Nairn (2025) detail 25 years of community service learning in environmental projects, proposing frameworks for classes. In educational settings, this connects students to real communities, fostering cultural empathy. It is observed that, by involving service, students not only learn techniques, but also internalize social impacts, reducing gaps in unequal contexts. Beagon et al. (2022) identify competencies for SDGs, including PBL as key to cross-cultural collaboration. These approaches transform pedagogy, making learning active and relevant, preparing engineers for global challenges with cultural sensitivity.

PBL, by focusing on real problems, allows students to confront first-hand ethical dilemmas, such as balancing costs with community benefits in multicultural areas. In Panama, for example, projects involving service in Garifuna communities have shown how students gain cultural proficiency by adapting designs to local traditions. In addition, the scalability of Miao et al. (2024) suggests that, with modest resources, hybrid versions can be implemented, combining virtual and face-to-face to reach more students. Another aspect is evaluation: instead of traditional exams, priority is given to portfolios that reflect sustainable impacts, encouraging continuous reflection. From a contextual perspective, integrating community service strengthens university-society ties, generating valuable feedback that refines curricula. This not only raises motivation, but cultivates engineers committed to equity, transforming education into an engine of inclusive development.

Inclusive and Collaborative Approaches

Inclusion is at the heart of multiculturalism. Pradhananga & ElZomor (2023) develop social sustainability knowledge and cultural proficiency in future builders using social media-based learning and PBL. Their results show greater awareness of unconscious biases and better cross-cultural communication. In Panama, with its diversity, this resonates; similar concept maps have been used, and students gain empathy.

Fortuin et al. (2023) propose border-crossing learning trajectories, supporting interdisciplinary and cultural collaboration. Its learning mechanisms-identification, coordination, reflection, transformation-are valuable for sustainable engineers. Hartikainen et al. (2022) examine student perceptions of teaching, with atmosphere created by teachers influencing emotions. Procedures such as active tasks evoke pride or frustration, key to motivation in diverse contexts. Cobian et al. (2024) promote inclusive science, integrating social identities with scientific identity in STEMM. Manuel et al. (2023) intersect culturally responsive pedagogy with engineering design in high school, improving engagement.

Table 2 summarizes inclusive approaches, with columns for dimension, impacts on students, connection to sustainability and references, focusing on multiculturalism.

TABLE 2. *Dimensions of Inclusive Approaches in Multicultural Engineering Education*

Dimension	Impacts on students	Connection with sustainability	References
Project-based learning	Improved collaboration and cultural awareness	Integrates social equity in sustainable designs	(Pradhananga & ElZomor, 2023; Higuera-Martínez et al., 2022)
Border crossing	Promotes interdisciplinary co-creation	Addresses global challenges such as climate change	(Fortuin et al., 2023)
Study abroad	Develops systemic thinking	Connects cultural contexts with techniques	(Özkan et al., 2024)
Inclusive science	Integrates social identities	Promotes equity in biomedical research	(Cobian et al., 2024)

Source: Author's elaboration based on Pradhananga & ElZomor, 2023; Higuera-Martínez et al., 2022; Fortuin et al., 2023; Özkan et al., 2024 and Cobaln et al., 2025.

This table highlights synergies between inclusion and sustainability. Explaining: these approaches, by varying in application, allow for local adaptations; for example, in educational settings, PBL with multicultural groups generates innovative ideas, explaining why they sound conversational by including anecdotes, and strengthening community ties in sustainable designs. It is observed that collaboration, as in Fortuin et al. (2023), transcends disciplines, bringing together engineers and anthropologists for holistic projects. In contexts such as Latin America, where cultural barriers are common, these methods reduce conflicts by promoting co-created solutions. In addition, considering emotions (Hartikainen et al., 2022) ensures that inclusion is not superficial, but addresses frustrations for genuine engagement. Another benefit is the transfer to professional practice: students trained in this way take empathy to real projects, mitigating inequalities. In perspective, expanding these approaches requires resources, but it starts with simple workshops that cultivate reflection, evolving into inclusive curricula that honor diversity as a key asset.

International Programs and Systems Thinking

International programs broaden horizons in sustainable engineering education. Özkan et al. (2024) promote systems thinking through study abroad, connecting technical and contextual aspects in countries such as China. This prepares for multicultural projects, such as infrastructure in indigenous regions, where the cultural context is decisive. MacDonald et al. (2022) align objectives in global graduate engineering programs, recommending interdisciplinary groups. His suggestions emphasize co-creation, ideal for sustainability in diverse contexts.

Bergman et al. (2022) explore experiences in intercultural group work, transcending labels. Jiang et al. (2022) investigate learner agency in cross-cultural PBL. These approaches build resilience, allowing students to navigate differences for innovative solutions. In perspective, programs like this not only teach; they transform visions, making engineers see holistic systems where culture and sustainability are intertwined. In a globalized world, these virtual or face-to-face exchanges mitigate gaps, such as exposing Panamanian students to Asian water management practices.

In addition, systems thinking helps to anticipate impacts, avoiding errors in multicultural environments. Another aspect is adaptability: in times of restrictions, such as pandemics, hybrid formats that maintain profits are chosen. In educational contexts, integrating these programs increases motivation, as students return with fresh perspectives, enriching local classrooms. Finally, it is suggested that these programs be evaluated with qualitative metrics, measuring not only knowledge, but also changes in attitudes towards diversity.

Integration of Sustainability in Higher Education

The integration of sustainability into higher curricula closes the pedagogical cycle. Bolstad et al. (2025) offer educators' perspectives on integrating sustainability into electronic engineering programs, applicable to civil. Their cases highlight ongoing evaluations to ensure relevance. Beagon et al. (2022) detail competencies for SDGs, emphasizing cross-cultural collaboration. This is essential in multiculturalism, where sustainability implies respect for local practices.

Hartikainen et al. (2022) analyze student emotions triggered by teaching atmospheres, key to sustainable motivation. In educational environments, integrating these elements ensures that sustainability is not abstract, but lived, preparing engineers for an interconnected world. It is noted that, in universities such as Panama's, where resources vary, they start with modules integrated into existing courses, moving on to specializations. In addition, by linking sustainability with multiculturalism, issues such as equity in access to resources are addressed, fostering ethical debates.

Another benefit is interdisciplinarity: collaborations with social sciences enrich approaches, such as when analyzing cultural impacts of green projects. From a practical perspective, teachers must be trained to guide these integrations, avoiding curricular overload. It is suggested to use local cases, such as the Panama Canal, to illustrate real sustainability, making lessons relevant and motivating. This transforms higher education into a space where sustainability is lived as an ethical and cultural commitment. These innovations, from virtual reality to PBL, weave a pedagogical tapestry that makes civil engineering sustainable and multicultural.

Cases in Several Countries that Broaden the Empirical Basis of the Study

In Germany, for example, the use of immersive virtual reality for carbon-neutral development modules shows indicative results of improvement in both conceptual understanding and student engagement, as it provides an environment to simulate complex decisions with both ethical and environmentally transferable implications to other geographies (Hu et al., 2025).

In China, the use of study-abroad programs to develop systems thinking in which technologically-based content articulates with sociocultural contexts and reinforces students' ability to anticipate side effects of engineering solutions in culturally distinct communities (Özkan et al., 2024).

In the case of Australia and New Zealand, the implementation of project-based learning acquires scale and provides positive evidence of curriculum sustainability and curricular scalability, thus reaffirming problem-solving and portfolio-based assessment approaches, facilitating the transfer of learning to multicultural and multilingual professionalized contexts (Miao et al., 2024).

Complementarily, trajectories of "border crossings" have also been documented that favor co-creation in an interdisciplinary and multicultural manner, enabling coordination and reflection competencies that, in turn, sustain collaboration in heterogeneous teams (Fortuin et al., 2023). These types of dynamics become more present when incorporating findings in the realm of cross-cultural group work and learner agency since, prolonged exposure to different cultures serves to advance the balance of participation and evenly negotiate meanings during the completion of complex projects (Bergman et al., 2022; Jiang et al., 2022).

Similarly, the literature emphasizes that teaching climate and classroom procedures are emotional triggers that need to be managed to sustain motivation in culturally diverse cohorts (Hartikainen et al., 2022). In North America, there have been

multiple experiences of integrating social justice frameworks into civil engineering courses, combining professional identity, diversity, and inclusive work with technical decision making, leading to sensitivity to distributional impacts and situated ethical deliberation (Casper et al., 2021; Casper et al., 2024).

Such initiatives are aligned with a set of educational practices, with classroom levels - elaborated for constant application - and culturally responsive pedagogy strategies in pre-university education, of which the flow of diverse talent for engineering stands out (Vaden et al., 2025; Manuel et al., 2023); in a parallel sense, elective courses in macroethics in energy and sustainability have evidenced a good way of linking technical knowledge and moral deliberation in global contexts (Jin & Daher, 2024).

The connection between academia and industry also presents interesting advances for social sustainability, as collaborations make it possible to couple learning outcomes and work practices to bridge the gap between vocational training and professional practice (Pearson et al., 2025).

At the sector level, proposals have been made for indicators to measure diversity, equity and inclusion with respect to the construction workforce, and barriers and opportunities for their adoption and implementation have been synthesized, generating an institutional roadmap that feeds back into curriculum design and continuous improvement (Karakhan et al., 2021; Choi et al., 2022; Heydari et al., 2024).

Finally, the recommendations for the alignment of goals in global graduate programs and the identification of competencies to the SDGs give rise to translate these lessons into curricular architecture, ensuring fit between formative purposes, methodology and assessment (MacDonald et al., 2022; Beagon et al., 2022; Bolstad et al., 2025).

In sum, these comparative cases show that the combination of technological immersion, contextualized PBL strategy, cross-cultural co-creation, explicit social justice and academy-industry linkages generate consistent improvements in technical and socio-cultural competencies. The incorporation in this study strengthens the development section and provides the international empirical basis from which pedagogical strategies for sustainable civil engineering in multicultural contexts could be adapted locally (Park et al., 2021).

Discussion and Conclusions

In discussing these findings, it emerges that pedagogical innovations are not a panacea; they face barriers such as institutional resistance or lack of resources. For example, implementing virtual reality (Hu et al., 2025) requires investment, which is challenging in developing countries, where educational budgets often prioritize basic infrastructure over advanced digital tools. However, the benefits outweigh: students with humanitarian identities (Park et al., 2021) are more resilient in multicultural contexts, able to adapt to complex social dynamics that go beyond structural calculations. Compared to experiences in Panama, mixing PBL with local elements reduces attrition, as students see immediate relevance in their lives, such as applying sustainability concepts to urban problems in marginalized neighborhoods.

Multiculturalism adds complexity: approaches such as border crossing (Fortuin et al., 2023) help, but need cultural adaptation to avoid imposing Western models in Latin American contexts, where indigenous traditions demand deep respect. Future research

should measure long-term impacts, such as on professional careers, exploring whether these methods actually translate into inclusive work practices or whether they are diluted in the face of market pressures. The tables above illustrate this: Table 1 shows technology as a cultural bridge, facilitating virtual access that democratizes learning; Table 2 emphasizes inclusion for equity, highlighting how dimensions such as PBL foster not only skills, but personal transformations. In contextual perspective, these methods improve educational work, varying lessons to engage everyone, but they also raise questions about scalability: How to replicate study programs (Özkan et al., 2024) in regions with mobility limitations?

In addition, the role of industry in this equation must be considered. Heydari et al. (2024) and Choi et al. (2022) review diversity in the AEC industry, noting that, without alignment between academia and work, humanitarian identities formed in classrooms may clash with hierarchical corporate cultures. Pearson et al. (2025) propose collaborations to advance ESG principles, suggesting bridges between education and professional practice. In environments such as Panama, where the Canal represents an icon of global engineering, integrating these perspectives could mitigate inequalities, but requires policies that encourage inclusion. Another critical point is emotional motivation: Hartikainen et al. (2022) highlight how teaching atmospheres influence student emotions, implying that innovations fail if they do not address cultural frustrations. It is observed that in regions with high diversity, such as Latin America, these emotional barriers can be amplified, requiring approaches that prioritize psychological well-being. In addition, future lines should explore how to measure success beyond academic metrics, incorporating community testimonials to validate real impacts. In short, while these pedagogies promise a sustainable future, their success depends on overcoming systemic obstacles, fostering ongoing dialogues between educators, students and industry to refine approaches that are truly transformative. This not only enriches the discussion, but also invites concrete actions, recognizing that cultural equity is key to civil engineering that benefits all.

In conclusion, pedagogical innovations are essential for sustainable civil engineering in multiculturalism. From humanitarian identities to virtual reality and PBL, these approaches prepare empathetic and competent engineers capable of addressing challenges such as climate change with a cultural lens. It is recommended to integrate into curricula, train teachers and continuously evaluate, but Latin American institutions are also urged to adapt these methods to local realities, such as incorporating ancestral knowledge into urban designs. This not only builds structures; it builds just societies, where social equity is intertwined with environmental preservation.

Furthermore, this educational transformation requires an institutional commitment: universities must foster partnerships with communities so that service learning (Knox & Nairn, 2025) is not sporadic, but a curricular pillar. In a broader vision, imagine a world where engineers trained in this way lead projects that respect diversity, reducing urban inequalities in regions such as Latin America. We must continue to innovate, because the future demands it, prioritizing evaluations that measure not only technical knowledge, but also long-term social impacts. It also suggests policies that encourage scholarships for international programs, expanding access to students from low-income backgrounds. Finally, this article calls educators and policy makers to action, recognizing that true sustainability arises from inclusive pedagogies that honor multiculturalism as a driving force for progress. This closes a cycle, but opens the door to

further research into practical applications, ensuring that civil engineering evolves towards a more humane and equitable role.

This reflection on pedagogical innovations not only summarizes a path followed in the literature review, but also projects a horizon where civil engineering reinvents itself as an inclusive and responsible discipline. In contexts such as Panama's, where multiculturalism pulsates in every corner, it is evident that the methods discussed, from virtual reality that simulates global scenarios to service learning that anchors knowledge in real communities, are not mere academic tools, but catalysts for profound social change.

It is observed that by fostering humanitarian identities, future engineers are cultivated with empathy that transcends structural calculations, allowing designs that respect ancestral traditions while addressing environmental urgencies such as climate change. In addition, the integration of social justice in curricula ensures that equity does not remain an abstract ideal, but is materialized in labor practices that mitigate urban inequalities, especially in Latin American regions where megaprojects have left traces of exclusion.

In this line, the proposed recommendations, such as interdisciplinary alliances and continuous evaluations, emerge as concrete steps towards transformative education. Institutions are urged to prioritize these approaches, recognizing that true progress lies in preparing professionals who see diversity not as an obstacle, but as an invaluable resource.

Future research could explore metrics to measure long-term impacts, incorporating community voices to validate whether these methods actually build more just societies. In essence, this paper does not conclude a debate, but drives it forward, reminding us that authentic sustainability emerges when civil engineering embraces multiculturalism with humility and vision, contributing to a world where every bridge built unites not only lands, but shared cultures and hopes.

Conflict of Interest

The author declares that he has no conflicts of interest.

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