HCD TO ADDRESS THE WATER CRISIS. A MULTI-CASE APPROACH

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ABSTRACT
Access to clean water has been raised by the UN as one of the greatest challenges of humanity, located in SDG number 6. This situation is a reality in many places, where highly extreme conditions are faced, long drought seasons followed by intense storms that overflow and destroy cities, Monterrey, Mexico, has lived this for decades, however the situation worsened due to factors such as mismanagement by the government, abuse by private companies and lack of water care culture of citizens.
Also, there is a strong need to develop professionals who can address complex projects through design methodologies and who are able to propose and develop innovative solutions, focused on the needs of people and considering the impact of such solutions on biodiversity by creating sustainable projects with high social impact. The students used the Human-Centred Design (HCD) to integrate affected communities in the design process.
This article examines the results of projects carried out between 2021 and 2024, all of which address challenges related to water. The projects were developed by students in their fourth semester of bachelor's degree in design at Tecnologico de Monterrey. The main aspects analysed were water use, management and recycling, prevention of water pollution, rainwater collection, quality monitoring, types of users, as well as commercial feasibility and user experience. This article discusses key lessons learned and provides a framework for future projects that seek to address water supply issues through a human-centred approach.

Keywords: Higher education, educational innovation, water crisis, sustainable solutions, Human Centred Design (HCD)

1 INTRODUCTION
Given the growing global water crisis, access to clean and potable water for human consumption has been identified by the United Nations as one of humanity's greatest challenges, positioned within Sustainable Development Goal (SDG) number 6 clean water and sanitation[1]. With less than 10% of water extraction allotted to domestic uses, the remaining water supports the life cycles of products and services. This situation is a reality in many parts of the world[2], particularly in Mexico, where highly extreme conditions are faced. Monterrey, Nuevo León, is one of the cities that has been closely experiencing this situation for decades. The distribution of water resources does not align with the geographical distribution of the population or the economic productivity of different regions[3]. In recent years, the situation has worsened due to various factors such as intense droughts, poor government management, private companies' abuse, and a lack of water conservation culture among citizens. Moreover, water quality is compromised by the contamination of surface and groundwater sources, affecting public health and reducing the availability of water for human consumption[4].
In Mexico, nearly 22 million people lack access to potable water in their homes, and an additional 10% have no access to water at all[3]. Deficient infrastructure and the lack of wastewater treatment exacerbate water quality issues and perpetuate inequalities in access. Faced with this crisis, collaboration between governments, businesses, and non-governmental organisations is essential but insufficient [5, 6]. It becomes urgent to propose solutions that not only benefit people but also promote the wellbeing of all living beings. This growing crisis can be reconceived as a design opportunity[7], besides political and technological solutions, human centred design responses are needed to mitigate and anticipate water scarcity. It is crucial to determine what changes are required in the systems and who should be involved in the solutions[7].

The need arises to develop design professionals capable of addressing complex projects and develop innovative solutions focused not only on people's needs but also considering the impact of these solutions on biodiversity. These professionals should create sustainable projects with high social impact [5], providing new perspectives on how to address environmental challenges through design methodologies. For this multi case approach, students used the Human-Centred Design (HCD) methodology [8], placing people's needs at the centre of the design process[9]. In the context of water supply issues, this methodology has been used to develop effective and sustainable solutions by integrating the affected communities and diverse stakeholders at every stage of the process, allowing the generation of innovative solutions but also raising awareness and promoting more conscious water consumption habits and water management practices.

2 METHODOLOGIES

This article is a multi -case that examines the results of five design projects conducted between 2021 and 2024, all addressing design challenges related to access, distribution, and water quality in vulnerable communities in Mexico. The projects were developed by students coursing the fourth semester of the Design Bachelor at Tecnologico de Monterrey and were executed by teams of three students over a total of 15 weeks. The HCD methodology was used to tackle all the design challenges and the structure outlined in the course syllabi was adapted to define the stages and activities to be considered in the design process[10]. The five cases were selected as a sample to present a variety of solutions and contexts to enhance the value of the HCD approach to solve complex problems.

Students conducted the projects across three consecutive courses, each within an intensive 5-week period during the same academic semester and in collaboration with a Partner organisation, which could either be a public or private entity acting as a client who presented a real-world problem to the students and with a group of users defined by the organisation. Each course had a clear objective and a specific deliverable, which would serve as the basis for the next one. In the first course the problem was outlined, and the research phase was conducted to build empathy by understanding the needs of the users, during this stage observations, field visits and interviews were conducted resulting in a design brief document. During the second course students used diverse tools as brainstorming and ideation to propose potential solutions focusing on creativity and innovation, then in collaboration with the users, the best proposal was selected and detailed design was undertaken generating digital and physical prototypes for user testing and improvement. Finally, in the third course a Product Service System (PSS) strategy was defined to integrate the solutions into the current water management system and avoiding product sale and disposal by proposing new service integrations and holistic approaches that benefit and empower users in the Mexican communities.

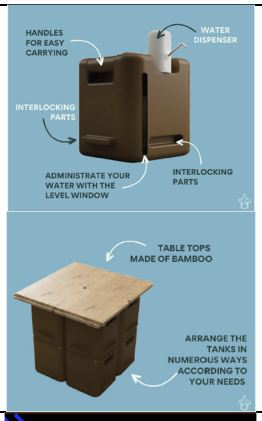
Various stakeholders were involved in the projects, each with a particular role:

- **Faculty**: Professors who are responsible for structuring the project, providing guidance and necessary resources, and coordinating the objectives and phases of project development.
- **Students**: who developed the project in collaboration with the Partner organisation.
- **Partner organisations**: clients who present the design challenge, define the end users, and share their knowledge with the students. The projects were carried out in collaboration with the following organisations:
  - **Patronato del Parque Rufino y Olga Tamayo**: A non-profit citizen association dedicated to improving, conserving, and preserving Rufino Tamayo Park [11].
  - **PROVS**: An NGO formed by citizens committed to service, sustainable development, and reducing inequalities. [12].
  - **Servicios de Agua y Drenaje de Monterrey**: A governmental organisation responsible for supplying potable water to the state of Nuevo Leon [13].
  - **Iniciativa Campana-Altamira**: An intersectoral and community shared effort aimed to improve the quality of life of Campana-Altamira community. [14].
- **End users**: The group for whom the system is designed and who will ultimately use the product. They play a crucial role in defining needs and providing feedback.

3 RESULTS

Table 1 identifies the selected cases, considering the following aspects for analysis: (1) Project picture, (2) Project name, (3) Partner organisation, (4) Purpose, (5) Context of use and (6) PSS description.

Table 1. Selected Cases

Project picture	Project	Partner Organisation	Purpose	Context of use	PSS Description
	La cosecha (urban garden)	Parque Rufino Tamayo	Rainwater harvesting for irrigation in public spaces.	Public	Collective food cultivation, environmental education, rainwater harvesting, sale of organic products. App to promote sales and services.
	Aquacheck (water quality measuring device)	PROVS	Water quality monitoring	Domestic	Water quality monitoring device/mobile application that provides water treatment or filtration suggestions and data collection.
	Aqualounge (multifunctional water storage tank)	PROVS	Water storage and management in acute water scarcity situations	Domestic	Multi-functional returnable drinking water storage tanks for flexible, space-saving furnishings.
	Retorno verde (Fats, Oils, and Grease (FOG) Reverse vending machine)	Agua y Drenaje de Monterrey	Prevention of water pollution from FOGs	Public	Reverse vending machine reward system for household FOGs collection. App rewarding system.
	Glup (Shower water recycling system)	Iniciativa Campana-Altamira	Administration, recycling and sanitation	Domestic	System for filtering, storing and managing shower water for other domestic uses.

As a result of this research, it can be observed that the integration of various stakeholders is key to develop high-value projects that incorporate the users' perspectives based on their needs and realities, especially in the context of vulnerable communities where access to water is limited. A significant part of the value of these projects lies in involving and empowering the community, individuals, and

organisations to generate holistic and sustainable solutions in the long term, aiming at waste reduction and better water administration. Such is the case of the projects "La Cosecha" and "Retorno Verde," which seek not only better water resource management but also propose strategies that can generate income for users by incorporating a PSS and a reward system to motivate users. However, the study also revealed differences in the complexity of managing solutions for public versus domestic use. Public use products, such as "La Cosecha", require extensive coordination among multiple stakeholders, including government agencies and civic organisations, to foster community awareness and participation.
On the other hand, domestic use products, exemplified by "Glup", while easier to manage due to their private nature, necessitated a shift in personal behaviours and consciousness towards resource conservation because in this case the shower water is collected, filtered, storage and recycled for other uses at home. These differences highlight the importance of designing solutions that are contextually appropriate and user-centred, ensuring that they are both practical and impactful. Furthermore, these projects aim to integrate and empower citizens in managing the resources, allowing their active participation, whether at home or in public spaces. The case of Aquachek, presents a portable water quality monitoring system, which allows the user to carry it with them and take quick measurements to determine whether the water available is potable or not, the system offers two types of measurements and uses refillable cartridges, extending the lifespan of the product, it also comes with an app that allows the user to map and record data showing the location where the samples were collected. This system allows the user to have greater control over the water they consume. It was designed to address the needs of people who live near the river and collect water to cover their basic needs due to the lack of infrastructure and public services in the urban area where they live.
Figure 1 shows the example of “La cosecha” an urban garden in a public space that integrates rainwater collection, storage and management tanks for public use as well as commercial products and services that enhance the user experience and foster sustainable practices in the community.

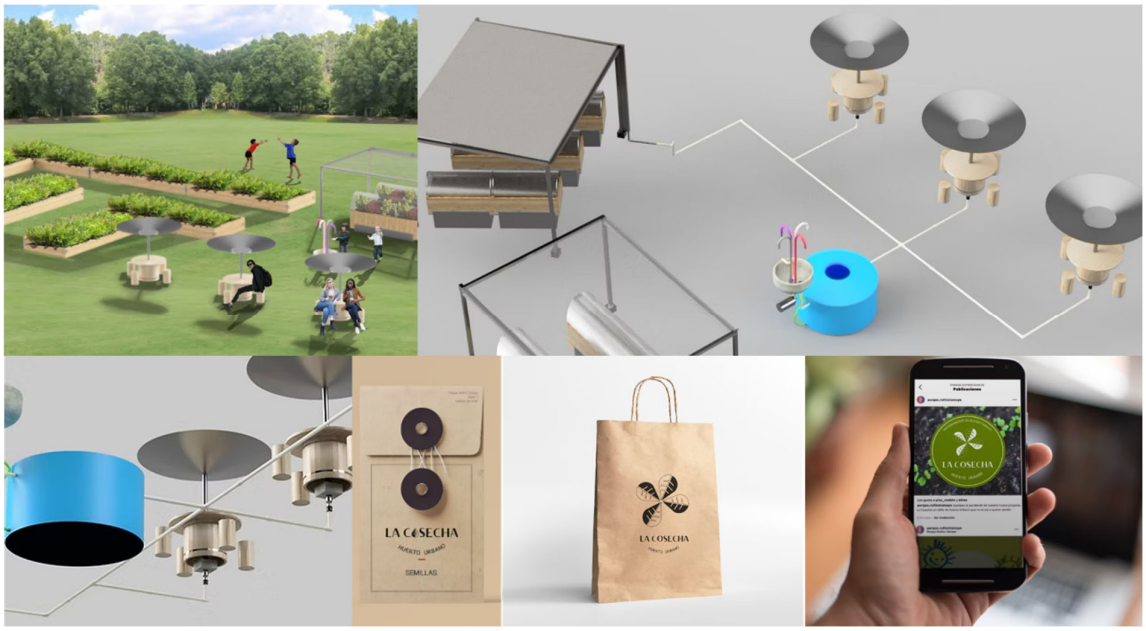


Figure 1. La cosecha: urban garden with a rain collection system that includes an underground tank and a fountain to administrate the water for plant irrigation. The PSS includes gardening workshops, organic products and seeds sales and an app for courses, purchasing and rewarding system

Among the PSS proposed by the students, mobile applications were the most recurrent, as they facilitate continuous interaction with users and support the gradual introduction of additional products or services, also reward programmes were integrated as an additional motivation, promoting gradual behaviour change while simultaneously raising awareness among users. Additionally, rental or leasing services stood out, particularly in cases requiring more complex infrastructure for operation or where systems necessitate water storage for subsequent household tasks management. Factors such as the required space for tanks or containers, user safety with stored water at home, filtering and sanitation to prevent

contamination and bacterial proliferation, and frequent cleaning of containers and pipes must be considered for an extended service. Another significant finding is that, although the projects targeted a broad range of users, it was identified during the analysis that the students primarily considered women as the main users of all the water systems because in the context of Mexico, women are responsible for managing household tasks and are the primary water users for various domestic chores.

4 DISCUSSION AND CONCLUSIONS

Water issues have been addressed through multiple methods and approaches, but this work is an HCD approach aiming to change behaviours among users and introducing principles of PSS in various cases of products for water saving, recycling, and pollution prevention to create more holistic and sustainable solutions. The findings from the multi-case study approach revealed several insights into addressing water issues through the integration of HCD and PSS principles. This combination not only facilitated innovative solutions but also underscored the significance of involving various stakeholders. Such collaboration ensures that the proposed solutions can generate long-term benefits [4, 15] emphasising the vital role of community participation for the success of the solutions. The application of user centred methods facilitated the development of product aimed at encouraging resource-conscious behaviour among individuals [16], fostering a culture of resource conservation and efficiency [17].

Mobile applications emerged as a prevalent tool among the proposed solutions, these applications, integrated with reward programmes, can be particularly effective in motivating behavioural changes while raising user awareness about water conservation [15]. The success of these digital tools underlines the importance of leveraging technology to enhance user engagement and promote sustainable practices [6].

Moreover, different types of PSS can enable various circular strategies, offering a versatile framework for sustainable water management [18] by shifting the focus from designing and selling physical products to create integrated systems of products and services, PSS can significantly reduce resource consumption [19, 20].

This study highlights the critical role of HCD principles in addressing complex water-related challenges. By engaging a diverse range of stakeholders, the students were able to develop holistic and sustainable solutions that consider the specific needs and realities of vulnerable communities. Projects such as "La Cosecha" exemplified the potential for integrated strategies to enhance water resource management while simultaneously creating economic opportunities for local communities.

Additionally, the findings emphasised the importance of a deeper understanding of the context, gender considerations, technological integration, and extended services in the development of user-centred water management solutions. The predominance of women as primary users in the cultural context of Mexico was a critical factor in the design process, ensuring that the solutions were tailored to the specific needs of those who manage household water usage. This article provides a framework for future design projects that seek to address water supply problems through a user-centred approach. Furthermore, it demonstrates that HCD can effectively address water issues, fostering sustainable water management practices and promoting the well-being of communities.

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REFERENCES

[1] United Nations Goal 6 Department of Economic and Social Affairs (n.d.). Retrieved February 3, 2025, from https://sdgs.un.org/goals/goal6.

[2] Redhu S. and Jain P. Unveiling the nexus between water scarcity and socioeconomic development in the water-scarce countries. *Environment, Development and Sustainability 2024*, 26(8), 19557–19577. https://doi.org/10.1007/s10668-023-03425-4.

[3] Pacheco-Treviño S. and Manzano-Camarillo M. G. F. Review of water scarcity assessments: Highlights of Mexico's water situation. *Wiley Interdisciplinary Reviews: Water 2024*, 11(4). https://doi.org/10.1002/wat2.1721.

[4] Oktor K., Dhuol M. G. R. and Ercan Kalkan M. Fog Harvesting: An Effective Solution to The Water Scarcity Problem. *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2024*, 28(4), 899–911. https://doi.org/10.16984/saufenbilder.1480488.
[5] Xie J., Qu S. and Xu M. Mapping water scarcity risks in global supply chain networks. *International Journal of Logistics Research and Applications 2024*. https://doi.org/10.1080/13675567.2024.2330591.
[6] Borquez B., Ahumada J., Mendoza M., Guillén R. and Contreras V. Addressing Water Scarcity in Isla Huichas, Chile: A Tecno-Economic Sustainable Solution World 2024, 5(4), 1367–1385. https://doi.org/10.3390/world5040069.
[7] Hadley P. A. Pivot: Reconceiving Water Scarcity as Design Opportunity Boom: A Journal of California 2013, 3(3), 95–101. https://doi.org/10.1525/boom.2013.3.3.95.
[8] Interaction Design Foundation - IxDF Interaction Design Foundation - IxDF. "What is Human-Centred Design (HCD)?" (n.d.). Retrieved May 31, 2025, from https://www.interaction-design.org/literature/topics/human-centered-design.
[9] Brown T. Change by Design: How Design Thinking Transforms Organisations and Inspires Innovation 2009. New York: Harper Collins.
[10] Instituto Tecnológico y de Estudios Superiores de Monterrey Instituto Tecnológico y de Estudios Superiores de Monterrey 2025. Retrieved February 2, 2025, from https://tec.mx/es/modelo-tec.
[11] San Pedro Parques 2024. Retrieved March 2, 2025, from https://sanpedroparques.mx/detalleParque?parqueRef=PRFT.
[12] PROVS A.C. PROVS 2020. Retrieved March 2, 2025, from https://www.provs.org/.
[13] Servicios de Agua y Drenaje de Monterrey I.P.D. Servicios de Agua y Drenaje de Monterrey I.P.D. 2022. Retrieved March 2, 2025, from https://www.sadm.gob.mx/.
[14] Iniciativa Campana-Altamira Campana-Altamira (n.d.). Retrieved March 1, 2025, from https://campanaaltamira.org/.
[15] Manzini E. and Vezzoli C. A strategic design approach to develop sustainable product service systems: Examples taken from the "environmentally friendly innovation" Italian prize. *Journal of Cleaner Production 2003*. Elsevier Ltd. https://doi.org/10.1016/S0959-6526(02)00153-1.
[16] Srivastava J. and Shu L. H. Encouraging resource-conscious behaviour through product design: The principle of discretisation. *Journal of Mechanical Design, Transactions of the ASME 2013*, 135(6). https://doi.org/10.1115/1.4024225.
[17] da Costa Fernandes S., Pigosso D. C. A., McAloone T. C. and Rozenfeld H. Towards product-service system oriented to circular economy: A systematic review of value proposition design approaches. *Journal of Cleaner Production 2020*, June 1. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2020.120507.
[18] Pieroni M. D. P., Marques C. A. N., Moraes R. N., Rozenfeld H. and Ometto A. R. PSS Design Process Models: Are They Sustainability-oriented? In *Procedia CIRP 2017* (Vol. 64, pp. 67–72). Elsevier B.V. https://doi.org/10.1016/j.procir.2017.03.040.
[19] Morseletto P., Mooren C. E. and Munaretto S. Circular Economy of Water: Definition, Strategies and Challenges. *Circular Economy and Sustainability 2022*, 2(4), 1463–1477. https://doi.org/10.1007/s43615-022-00165-x.
[20] Pieroni M. P. P., McAloone T. C. and Pigosso D. C. A. Configuring new business models for circular economy through product-service systems. *Sustainability (Switzerland) 2019*, 11(13). https://doi.org/10.3390/su11133727.