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Infusing Sustainability

A Compass-Led Intervention in Chilean Graduate Design Education

ABSTRACT

Design for Sustainability has evolved rapidly over the last decades as a response to unprecedented global challenges. Several models have been developed to address the need to design more sustainable products, services, and policies. These strategies are oriented towards more sustainable ways of living. The Compass, developed by the Index Project in Denmark, is a method that offers a framework to structure the design process while considering social, environmental, and economic sustainability aspects. This article presents an exploratory case study to infuse sustainability in design education using this method in interdisciplinary teams. The context is a master's degree offered by a design school in a Chilean university. The study's outcomes reveal that The Compass method is a dynamic and flexible structure for design in interdisciplinary teams. To strengthen its applicability, it could incorporate links to sustainability methods from various areas of knowledge that specifically address economic, environmental, or social aspects. Complementing The Compass with these sustainable approaches to confront the complexity of the challenges may facilitate the move from good ideas to feasible, sustainable design solutions in design and other fields.

Keywords:
Design for sustainability, interdisciplinary design, The Compass method, Design to Improve Life.

INTRODUCTION

Designers have been instrumental in creating goods and services that contribute to human development. Nevertheless, in the process, they have also, directly and indirectly, helped damage the environment (Andrews, 2021). This has happened due to designers' unreflective practices centred on creating increasingly questionable and unnecessary needs and wants (Papanek & Lazarus, 2005). Today, knowledge and practice of Design for Sustainability are fundamental to withstand unprecedented challenges. Therefore, design educators must rethink design pedagogy and practice to support designers and non-designers in assessing and transforming the values by which products, services, and systems are created. Stegall (2006) points out that this is not just an instrumental need but a sociological matter.

As moving towards sustainability is complex and covers numerous aspects, environmental leaders come from multiple disciplines and integrate diverse knowledge and mentalities into their work (Brundiers et al., 2010). Higher education institutions are challenged to foster interdisciplinary and experiential ways of learning and working (Denham et al., 2021) to produce combined knowledge given the world's challenges. Specifically in graduate design programs, developing ecological literacy and critical and systemic thinking is fundamental to integrating new mentalities that reflect and act for more sustainable living conditions.

In this context, the Danish non-profit organisation *The Index Project®* created *The Compass®* in 2012, a human-centred design method with a strong orientation towards sustainability. This method has been used globally to inspire, educate, and engage people in designing sustainable solutions to global and local challenges. The organisation promotes applying design and its processes to create better solutions in vital areas of people's lives and communities worldwide. Although The Compass was developed more than ten years ago, there are no empirical studies about its use or performance in higher education settings.

The educational team of *The Index Project* trained eighteen design professors of Universidad del Desarrollo (UDD) in Chile in 2017 to apply *The Compass* in their design courses. Specifically, the graduate master's program has used it as its methodological model for five years. As part of the faculty, one of the authors trained these groups of students from diverse backgrounds. We have learned about the method's potential through the years. We have also reflected on challenges and future development needs. The above has led us to question: How does *The Compass method* contribute to the design process of interdisciplinary teams in the context of a Master of Design and Sustainable Innovation program in Chile? What does the interchange between students from different backgrounds reveal about using The Compass as a method in the master's course?

To address these questions, we conducted an in-depth qualitative case study to explore the applicability of The Compass method as a framework for interdisciplinary teams to define sustainability challenges and propose solutions. The study context was the *Innovation Through Design* course of the Master of Design and Sustainable Innovation at Universidad del Desarrollo in Chile, which was dictated in 2022. In this course, The Compass is taught through a theoretical-practical approach to engage students in a critical design process by working collaboratively to solve a sustainable design challenge.

UNDERSTANDING SUSTAINABILITY

The world faces complex challenges posed by environmental crises, climate change, social instability, increasingly scarcer and more expensive resources, and a growing population. The traditional development model has proven unviable due to constraints in the availability of resources, scarcity, and environmental damage (Ellen MacArthur Foundation, 2015). Realising this, Sustainable Development was proposed some decades ago in the United Nations report *Our Common Future* as an alternative to the current unsustainable development model that has led to worldwide environmental deterioration while still not satisfying the basic needs of a significant portion of humanity (UN, 1987). In this report, sustainability refers to the ability of ecosystems to sustain themselves and society over time. It analyses the various elements and interactions of the problem, presenting a systemic approach to sustainability.

Environmental, social, and economic sustainability can be identified. Environmental sustainability aims to maintain human life support systems that provide source and sink functions (Goodland, 1989). The source function provides our material inputs, such as food, water, air, and energy, while the sink function assimilates our outputs or waste (Goodland, 1995). These life support systems are already deteriorated, so a transition to environmental sustainability is urgent (Goodland, 1995). As important as social and economic sustainability are, these cannot be achieved without environmental sustainability; hence, the relevance of attaining environmental sustainability in a systemic way over the operational emphasis it has had for decades (Ceschin, 2016).

Ecological, environmental and design literacy
Today, instrumental approaches to design and sustainability cannot solve the complexity of problems that the world faces. According to Boehnert (2015), decision-makers will only design for sustainability if they develop their ecological literacy first. The concept of ecological literacy was proposed by David Orr in 1992 in his seminal book *Ecological Literacy.* Ecological well-being and ecological knowledge are defined under this concept as central to the pursuit of sustainability (Boehnert, 2015). Ecological literacy is not a set of content knowledge but rather a deep understanding of the interdependence between natural processes and human ways of living (Orr, 1992). Orr highlights that the world works in fragmented ways focused on individualistic mentalities. Ecological literacy moves towards developing ways of perceiving systemic interconnections to deal with the complexity of ecological, social, and economic crises (Orr, 1992).

Denham et al. (2021) questioned humankind's role in ecological literacy. They coined the concept of *collective environmental literacy*, based on a holistic comprehension of the human experience, where people's practices grow and evolve at an individual and especially a collective level. In their view, literacy emphasises that learning and behaviours can be developed iteratively over time. But how can ecological or environmental literacy be taught?

Ecological literacy is 'taught' in diverse ways in higher education. An applicable approach for design education is the dispositional view of thinking used by Koyama and Watanabe (2023). The three components of a dispositional approach are inclination, sensitivity, and ability. Inclination refers to creating a foundation where people are inclined towards ways of thinking and acting that lead to sustainability. Sensitivity is related to sensing when, for example, decisions are moving in the wrong direction. Ability is the capacity to perform using the necessary skills to execute actions for sustainability. The authors argue that a critical understanding of sustainability is needed for the dispositional development of ecological literacy.

A question arises: What is the relationship between design and ecological literacy? In our view, ecological literacy is a component of design literacy for designers and non-designers, and they are indivisible. There is no design literacy without the ability to *critically problematise sustainability* (Koyama & Watanabe, 2023). Micklethwaite (2022) states that sustainability is a transversal competence and summarises in five main statements their knowledge of teaching a graduate course to frame sustainability in design: 1) Sustainability is a social, not just an environmental agenda; 2) Sustainability presents us with wicked problems, which have no right or wrong answers; 3) Sustainability-Directed Design Practice arises from the sustainability literacy of the designer; 4) Sustainability derives from mindsets and worldviews, not just methods and materials; 5) Sustainability is an emergent property of systems, not a quality of products. These statements are aligned with the approach to design for sustainability proposed by The Index Project through The Compass.

Design education for sustainability and methods to design for sustainability.
Educating for sustainability is described in the literature as a fundamental aspect of design curricula (Andrews, 2021; Stegall, 2006; Orr, 1992). Professionals educated in sustainability will be able to incorporate sustainable thinking in their projects and understand local needs, cultures, and ecosystems to produce adequate solutions to diverse challenges.

A wide range of approaches, models and methodologies have been developed to help designers evolve to practise with responsibility for the environment and sustainability effectively. These

approaches come from various areas of knowledge and address the economic, environmental, or social aspects of sustainability, human well-being, physical product design, manufacturing, and engineering, focusing to some extent on the user's experience. Also, different scopes can be identified, ranging from wide-reaching, high-level, systemic planning and decision-making to detailed design in the development of goods and services. Finally, some design approaches for sustainability focus on the product's physical characteristics and its use phase as a driver to improve sustainability.

Starting in 1970, Green design concentrated on product innovation by lowering environmental impact by redesigning individual product qualities (Ceschin et al., 2016). Ecodesign (Brezet & Van Hemel, 1997) advanced product innovation for sustainability by defining a series of strategies to manage and assess the ecological aspects of a design through its lifecycle based on the Ecodesign strategy wheel. The Cradle-to-cradle approach (Braungart & McDonough, 2002) proposes that products should be designed so that after their useful life, the materials they are made from become 'nutrients' for new products or living organisms. The Circular Design Guide developed by the Ellen McArthur Foundation (EMF) and IDEO (www.ideo.com) was created to support circular principles in organisations and has proven effective as a hands-on guide (Reigado, Fernandes, Saavedra, Ometto & Da Costa, 2017). EMF's theoretical foundation relies strongly on the Cradle-to-Cradle approach (Huerta, 2021).

The Circular Economy model has been proposed as a system that is *regenerative by intention and design* (EMF, 2015), shifting the disposal *end of life* of products and systems for a restoration concept to *design out* waste that implies reusing materials, using renewable energies, and reducing waste by rethinking productive systems to favour disassembly, reuse, and produce cleaner energy. As presented by EMF, the circular economy approach does not explicitly address sustainability. However, it is worth paying attention to due to the increasing interest it has raised among businesses and governments.

In the context of studying the value of design methods and approaches for a wider population (other than professional designers), Lutnæs (2021) explores critical thinking to focus design on the well-being of people and the planet, which can improve people's lives and hopefully influence how we live in the future. Stegall advocates for *intentional design*, product design that supports positive and constructive ways of living. He states that, rather than just focusing on the product's physical characteristics and environmental impact, design should care more for the user's needs and behaviours to address product sustainability (Stegall, 2006).

In the last two decades, approaches to design for sustainability have returned to reflect on sustainability's social component. Design for Social Innovation and Systemic Design move from a product and process orientation to *large-scale system-level changes* (Ceschin, 2016). On the other hand, Design for Sustainable Behaviour has evolved from a product focus to make people adopt sustainable behaviours (Ceschin, 2016) to a well-being approach to improve people's quality of life. Coskun et al. (2015) reviewed more than a decade of design research articles on design for sustainable behaviours. They found a lack of studies exploring the areas where design for sustainable behaviour change can impact the environment and developing strategies that can influence people's behaviours in a profound and lasting way.

Although design for sustainability has evolved and has been successfully mapped by the detailed work of design researchers (Gaziulusoy & Öztekin, 2018), newer conceptions take time to be introduced in educational practices (Micklethwaite, 2022). This is especially true for knowledge in design for sustainable transitions and system design. Design approaches focused on systems and people are adopting these views faster, as they do not depend on delivering tangible outputs and are less related to a defined type of design practice (Micklethwaite, 2022). The Compass suggests that design should be oriented towards improving people's lives and that these views need the collaborative work of designers and non-designers. In this study, we share the process and results that can be obtained using this framework in the context of a graduate design programme in Chile.

The Compass Design Method

The Compass®, developed by The Index Project®, is a human-centred design method with a strong orientation towards sustainability. Index is a Danish non-profit organisation with a global reach that

inspires, educates, and engages people in designing sustainable solutions to global and local challenges. The organisation promotes applying design and its processes to create better solutions in vital areas of people's lives and communities worldwide.

The Compass is a problem-solving and planning method that guides the design process of professional teams in navigating, focusing, and staying on track while encouraging curiosity, engagement, creativity, and innovative thinking. It is structured as a holistic and non-linear process that alternates between repetitions and progressions towards the desired impact of the design solution. A design is evaluated using form, impact, and context parameters in four phases: prepare, perceive, prototype, and produce. Design parameters and phases of the design process are displayed in Figure 1.
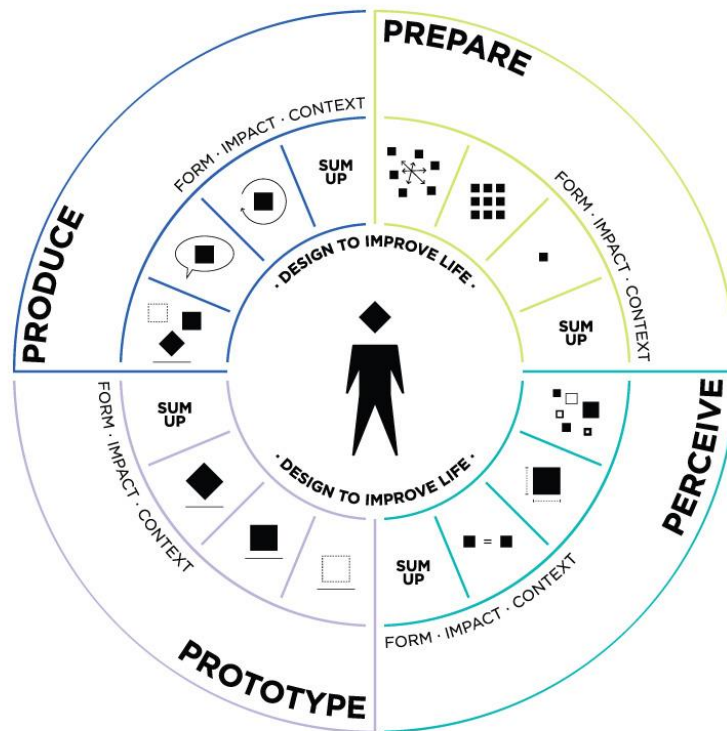

FIGURE 1. The Compass® method developed by The Index Project® comprises four phases that ensure the form-impact-context triad being assessed.

The parameter *Form* evaluates the design's surface, material, interface, colour, coherence, and aesthetics. In the case of intangible solutions, the form parameter refers to the structure and strategies that define the solution; *Impact* is centred on the relevance and potential of the design to improve people's lives and its economic and environmental sustainability; and *Context* focuses on the context in which the design will be inserted, the relevance of the challenge and the solution in the culture, and geographical location, in which it will be implemented.

Each of the four phases is focused on specific moments and purposes of the design process and contains three main actions plus a final sum-up activity. In the *Prepare* phase, working groups identify possible challenges and concretise the specific challenge they want to work with. This phase focuses primarily on the Impact parameter to address challenges that negatively affect people's lives. The *Perceive* phase focuses on the *Context* parameter. The design team refines and deepens their understanding of the challenge and characterises the potential users and target groups: the people affected by the challenge and how they are concerned, their needs and wants, and the specific characteristics of their context. In addition, the environment the design must work within and the

culture, geography, and infrastructure in the local context are identified. In the *Prototype* phase, ideas on how to solve the challenge are explored. The design solution starts to be developed using visualisation and modelling resources. Solutions are tested on users to evaluate them, identify problems, and reflect. Sometimes, this revision implies starting over. The phase focuses on the *Form* parameter since the group is working on developing and shaping their ideas. Finally, in the *Produce* phase, the group gathers all the material they have produced in the previous phases to gain an overview of the process. In the last sum-up of the process, the individual design teams' work is evaluated by peers based on all three Design to Improve Life parameters: *Form, Impact* and *Context.*

RESEARCH CONTEXT

Professionals of various disciplines, not only those trained as professional designers, have the opportunity and duty of leading sustainable innovation by considering the long-term implications of their design decisions. Motivated by an interest in incorporating sustainability as a relevant topic for design education for designers and non-designers, a case study was conducted to promote sustainable innovation in the context of a master's programme in design at the Universidad del Desarrollo in Chile.

The Index Project has been collaborating with this university in Chile since 2017. The Master of Design and Sustainable Innovation programme was created within the School of Design to explore The Compass's applicability as a model for interdisciplinary teams to develop solutions to complex challenges to improve people's lives. The programme is aimed at designers and non-designers. In five years, it has had more than forty students from diverse backgrounds, including design, engineering, business, journalism, social work, and education. Approximately ten per cent of students in this programme come directly from undergraduate programmes, and the rest are working professionals. The course Innovation Through Design aims to transfer The Compass through a theoretical-practical approach within this programme.

The Compass incorporates educational and creative tools and procedures that enhance the mindset-building process of interdisciplinary teams to empower them to integrate design as a way of living, thinking, and thriving towards sustainability. The Index Project acknowledges the relevance of Design Thinking and its creative methodologies to provide professionals with the skills needed in the 21st century, recognising that it is insufficient to resolve complex challenges (The Index Project, 2012). Although The Compass was developed in 2012, there are no empirical studies about its use or performance in educational or professional settings. Scholarly literature exploring its application is inexistent. This study aims to investigate the use of The Compass for sustainable innovation to contribute to the knowledge of design for sustainability with an empirical case study that includes application examples to compare the similarities, particularities, and differences of their design processes.

METHODOLOGY

We designed an in-depth qualitative case study to explore the applicability of The Compass method as a model to create solutions to complex challenges to improve people's lives. The case study approach was chosen to investigate the application of The Compass method within a natural context. The case study included data from the Innovation Through Design course, where twelve students participated. The focus was the final assignment, which consisted of a written report according to a given structure and a presentation of the results to the class through a ten-minute oral presentation.

The report asked groups to demonstrate skills to execute a complete Design to Improve Life cycle proposal using The Compass and reflect on a Design to Improve Life process, going through the four phases of the method (Prepare, Perceive, Prototype, Produce). The final reports were assessed according to the following parameters: Use of The Compass framework and techniques to conduct a Design to Improve Life process to solve a selected design challenge of the participants' choice; the reflection process followed, and informed decision-making based on documental and empirical data

collected; coherent and well-founded relation between the Form, Impact and Context parameters of the proposed solution.

Participants

Twelve professionals (four female and eight male) participated as students of the 2022 version of the course, coming from diverse disciplinary and professional backgrounds (industrial design, graphic design, business, educational psychology, and art). The instructors grouped the students in interdisciplinary teams to combine their disciplinary backgrounds and job positions.

Timeline and Activities

During the first week, participants attended an Empathy Workshop conducted by an expert in service design to get acquainted with studying specific contexts. During the second week, the training focused on introducing The Compass and its four phases. Then, each group of students explored a challenge they chose that had to be aligned with the United Nations' Sustainable Development Goals (SDGs) (UN, n.d.). The groups applied a whole Compass cycle from the third to the fifth week to propose design solutions.

TABLE 1. Summary of the course content and activities. The table describes the objectives, activities, and outcomes of each session. During sessions 3, 4, and 5, teams worked together to develop the group design project.

SESSION	OBJECTIVE	ACTIVITIES	OUTCOMES
1 *Empathy Workshop*	Introduce empathy for design and innovation.	Work in groups to recall good and bad personal experiences and identify opportunities to improve through the empathy perspective.	Understanding of experiences applying the three aspects of the empathy trilogy.
2 *Design Methods and The Compass*	Introduce The Compass within other design methods.	• Presentation of a Historical timeline of Design Methods. • Presentation on The Compass Method. • Discuss design synthesis and meaning making.	A common understanding of design's fundamental concepts. Overview of The Compass.
3 *Group Design Project* *PREPARE-PERCEIVE PHASES*	Apply techniques offered by The Compass for the first two phases of the design process.	Techniques: Open Space; Challenge Mind-mapping and Focus; Personas; Knowledge Mapping and Central Themes; Research Strategy.	Screen large topic areas. Structure large quantities of material. Empathise with other people's/ culture's/groups' needs and expectations.
4 *Group Design Project* *PROTOTYPE-PRODUCE PHASES*	Practise various techniques of collaborative ideation and prototyping techniques.	Techniques: Talking Waterfall; Idea Poker; Ideation mind-mapping; Oracle round; Fast Prototyping; Role Play.	Shape ideas physically and collaboratively and test them in role playing situations. Processing new knowledge.
5 *Group Presentations and feedback*	Present results and gather feedback.	Presentations by each group; Two stars and a wish feedback technic.	Recommendations to improve design results.

The students worked in synchronous activities during class hours and asynchronous independent work. Table 1 summarises the content covered during the course and the actions and techniques performed before and during the group project.

Design Project

The Design Project was the final assignment of the course. It consisted of developing a design solution related to one or more SDGs in groups of three students. The assignment was focused primarily on using The Compass and its techniques to structure the design process rather than on the detailed development of the design solution proposed by each group. During the sessions, groups participated in the same guided activities for each method phase, applying techniques offered in The Compass (selected by the instructors). As complementary reading and supporting material, students were given the *INDEX Design to Improve Life Teacher's Guide (2012),* a publication that thoroughly details the approach, phases, and techniques of The Compass. Table 2 displays information about the four design teams, their projects, and the SDGs addressed.

TABLE 2. Working Groups, participants' backgrounds, name of the project, and SDGs addressed.

GROUP	PARTICIPANTS' DISCIPLINARY BACKGROUND	NAME OF THE PROJECT	SUSTAINABLE DEVELOPMENT GOALS ADDRESSED
1	1- Designer 2- Business administrator 3- Industrial designer	DIPP PRACTICAL AND POPULAR DESIGN FOR EVERYONE	SDG 9: Industry, innovation, and infrastructure. SDG12: Responsible consumption and production.
2	1- Business manager 2- Industrial designer 3- Graphic designer	eCLETA REPLACEMENT SYSTEM FOR DECARBONISATION OF URBAN MOBILITY	SDG 7: Affordable and clean energy. SDG 11: Sustainable cities and communities.
3	1- Industrial designer 2- Business manager 3- Educational psychologist	NOT WATER: EACH DROP COUNTS Kit designed to generate awareness, valuation and optimisation in the use of water at home.	SDG 6: Clean water and sanitation. SDG 11: Sustainable cities and communities.
4	1- Designer 2- Business manager 3- Art teacher	TEDUCO CONSCIOUS EDUCATION ABOUT CHILDREN'S CLOTHING	SDG 11: Sustainable cities and communities. SDG 12: Responsible consumption and production.

Prepare Phase: To work on the first phase, we used two techniques suggested by Index to deepen knowledge and understanding of the topics selected by each group. *Open Space* is an active exercise of theme overviews. It consists of doing fast desktop research and combining it with prior knowledge about an issue to gather a shared understanding and a position to approach the following phases. *Challenge Mind mapping and Focus* are used to select and frame the specific challenge and recognise the variables implied in the problem that must be addressed using mind maps. Figure 2 displays the work developed by Group 3 when they discussed about water use in domestic contexts using a mind map.
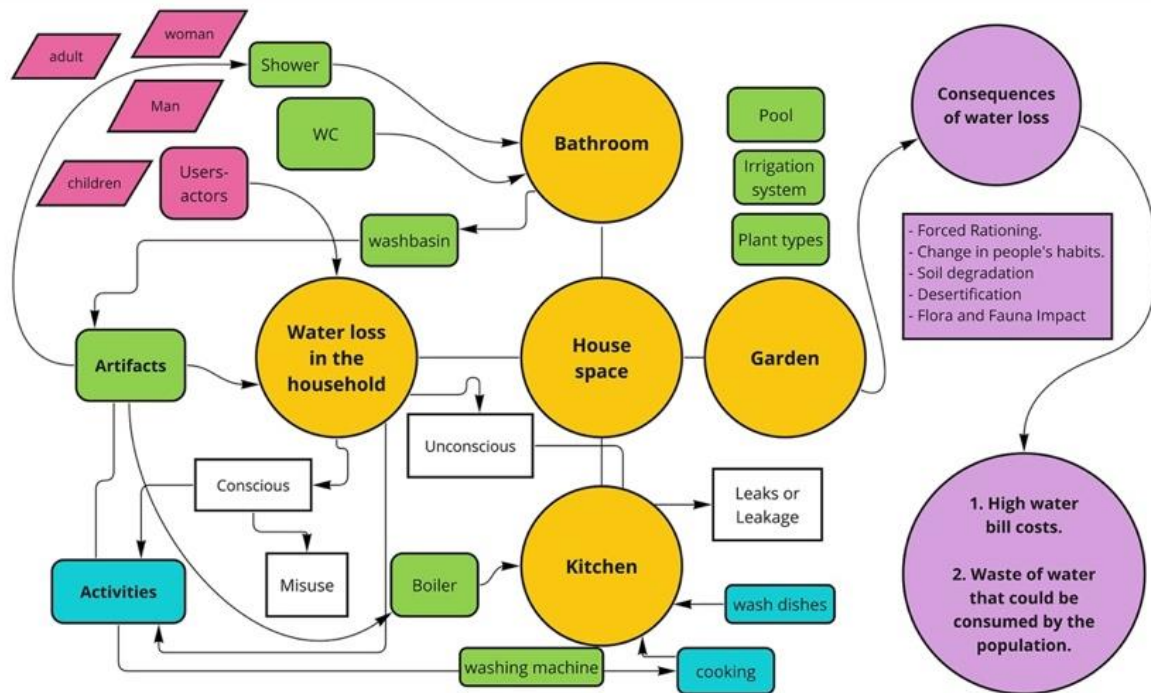
FIGURE 2. Example of Mind mapping. Group 3 (Not Water) developed this mind map during the Prepare phase to reflect on water use in domestic contexts.

Perceive Phase: During the second phase, work focused on defining and understanding users by performing fieldwork through interviews, observing real contexts, and representing *Personas* based on the gathered information. Afterwards, groups used *Knowledge Maps and Central Themes*, which use a table format to describe what the team knows, what they think they know, what they need to know and who will provide this information. Knowledge mapping evidence possible bias and directs research towards founded discoveries. Combining techniques and iterating during this phase enables defining target users with specific needs. Finally, each group elaborated a *Research Strategy* to organise the research work they needed to do through a second round of fieldwork. Figure 3 shows an example of Persona developed by Group 1 using the template proposed by The Compass. It also shows the template of the *Knowledge Maps and Central Themes*, which students used to organise their thoughts and needs.

Prototype Phase: In this phase, groups used techniques that stimulated creative thinking and collaboration. The *Talking Waterfall* is an uninterrupted dialogue in which all participants present ideas to the rest of the group without receiving judgment for a defined time. The *Idea Poker* is a series of cards with images that evoke possible topics to build creative, out-of-the-box ideas. Fast Prototyping enhances rapid solution models that promote discussion and collaboration as in other methodologies. Finally, all groups worked together to perform an *Oracle Round*. This is an active conversation technique in which half of the participants play the role of an oracle, and the rest ask questions about their projects. After the first round, roles are exchanged. In a short time, the opinions and insights of many people with diverse backgrounds and experiences are shared, contributing to the creative and critical thinking mindset characterising this phase. Figures 4 and 5 show images of the prototyping phase.
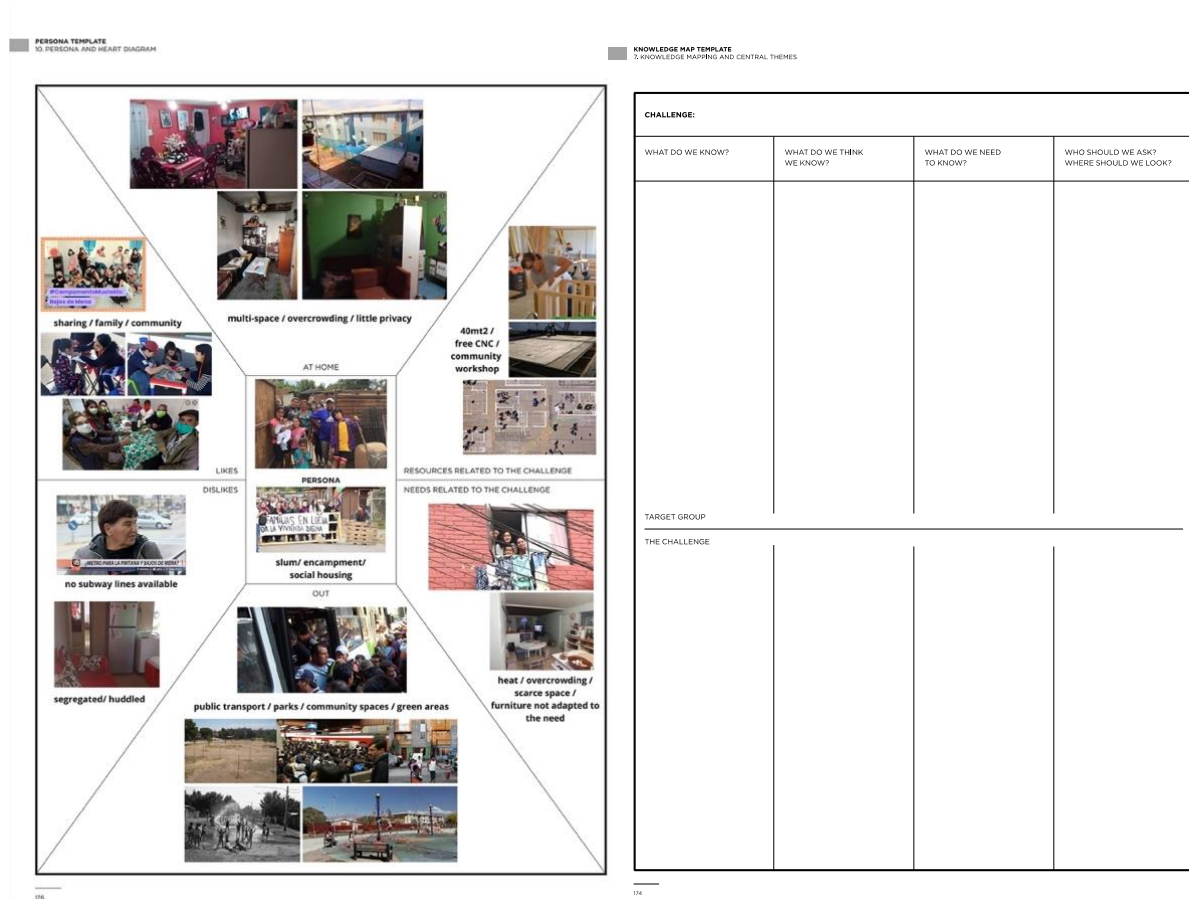
FIGURE 3. The Persona and Knowledge Map Template were filled out by Group 1 (DIPP) to reflect on their users' living conditions, problems, aspirations, and needs.

FIGURE 4. Fast prototyping sessions. Idea Poker cards were used to ideate, and Group 2 prototyped their solution ideas, using Lego pieces to visualise an electric bike station.

FIGURE 5. Fast prototyping sessions. The groups prototyped their solutions using various materials, such as Lego pieces, cardboard paper, masking tape, and plasticine.

Produce Phase: This phase was dedicated to preparing final deliverables and presenting them during the last session of the course. Each group showed for ten minutes using a digital presentation. The rest of the students gave them *Two Stars and a Wish*: two positive feedback comments and an opportunity for improvement. This was a relevant inflexion point for the projects, as they had time after the session to adjust and clarify before turning in their final report.

Data Collection and Analysis
The principal data source was the written reports the four groups delivered at the end of the course. Even though all groups were given the exact requirements regarding deliverables, the differences in their outputs were considered to understand Compass's use to deal with specific problems in different contexts and affect diverse audiences. The written content and images used in the final presentations were also considered.

A systematic document analysis was used to compare the reports, find patterns, and uncover and understand their meaning (Bowen, 2009; Merriam, 1988) in the framework of The Compass method applied by the four groups. The data was triangulated with observations performed during class sessions in written and photographic forms to reduce bias. A comparative matrix was produced to classify the documents' information using the following categories: Challenge, Motivation, User, Prepare phase, Perceive phase, Prototype phase, Produce phase, and Global reflections on the process.

The four projects were analysed, focusing on the data about using The Compass as a structure for their interdisciplinary design processes and the outcomes of the techniques applied to navigate the four phases. Special attention was paid to identifying moments of insight production and learning outcomes of each group.

OUTCOMES
To organise the results, we describe each group's challenge, motivations, and questions to contextualise the four projects. We then display the design solutions in the group's terms to support understanding the patterns found and the examples we give to illustrate them. Table 3 resumes the framework each group constructed for their design challenge.

TABLE 3. A framework of the Design Projects. Each group framed a challenge motivated by their research of the topic and the questions that arose using The Compass methodology.

GROUP	CHALLENGE	MOTIVATION	QUESTION
1 DIPP: PRACTICAL AND POPULAR DESIGN FOR EVERYONE	Improve people's quality of life by optimising spaces in homes with less than 40 M2.	"Understand the reality that many people in our country today face living and coexisting in small spaces and how that affects their quality of life".	*How could we simplify and improve the common areas to optimise space in urban housing of less than 40m2?*
2 eCLETA: REPLACEMENT SYSTEM FOR DECARBONISATION OF URBAN MOBILITY	Rethink the existence of Illegal bicycles with motor adaptations ('mosquito bicycles'), which are highly polluting, and complex to road coexistence.	"We chose this topic because it is a point of conflict with multiple sides".	*How could we offer an alternative to mosquito bikes to reduce their environmental impact?* *How can we encourage the users of the mosquito bikes to make this change?*
3 NOT WATER: EACH DROP COUNTS	Lack of information about water-saving technologies that can be used in households to reduce water consumption and bills cost.	"Generate collective awareness regarding the use of domestic water to produce changes in people's habits and reduce water consumption".	*What can we do to make our users: be aware of caring for water, use practical water-saving systems, and have incentives to modify their household consumption habits?*
4 TEDUCO: CONSCIOUS EDUCATION ABOUT CHILDREN'S CLOTHING	Harmful effects of the textile industry focused on babies' clothes.	"Develop new habits of use and consumption by providing educational information".	*How could we reduce the environmental impact of clothing used between 0 and 1 years old?* *How can we increase the reuse and recycling of the products already in circulation?*

Design solutions proposed by each group.
1. DIPP: Practical and Popular Design for Everyone
Collaborative app to optimise housing spaces equal to or less than 40 square metres (fig. 5).
Through this free-of-charge app and without the need to complete forms to access the application, users can enter the square metres of their home and the details and aspects of it (number of bedrooms, number of people residing in the space, and place of greatest use). With the information obtained, the system gives exact measurements of the proposed furniture according to the area requested. After this, the user can download the plans, materials list, and instructions for building them. If someone is unfamiliar with or prefers to outsource the building process, they can access a network of carpenters who will construct and install the furniture.
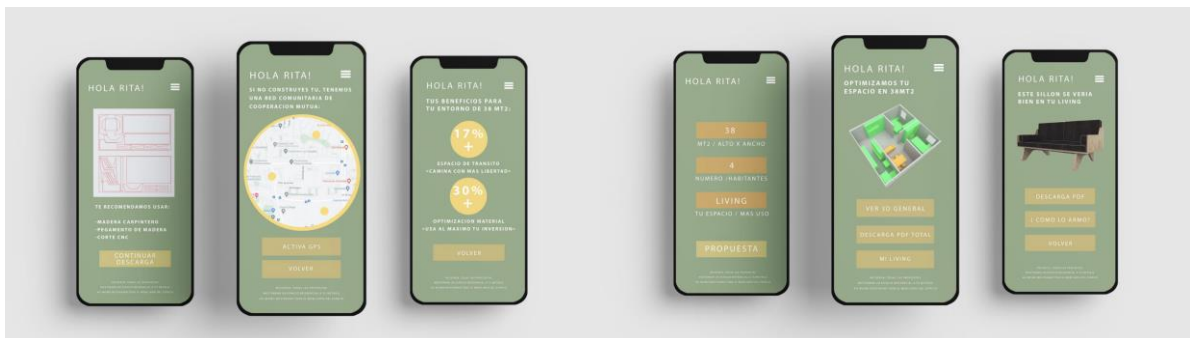
FIGURE 6. DIPP application mock-up. DIPP offers a system to design interiors adapted to the space and activities performed in a home. It suggests adequate configurations to optimise the use of space and the construction of customised furniture.

2. e-CLETA: Replacement system for decarbonisation of urban mobility

The solution proposed is e-CLETA (fig.7), a replacement system for decarbonising urban mobility. It expands the reach of the identified user to everyone who needs to move around the city with a sustainable and accessible means of transport. The service consists of replacing the need to own a mosquito bike or other means of transportation with a system of electric bikes for rent. Batteries and bikes are available at charging stations, and an app integrates the system to facilitate its use.
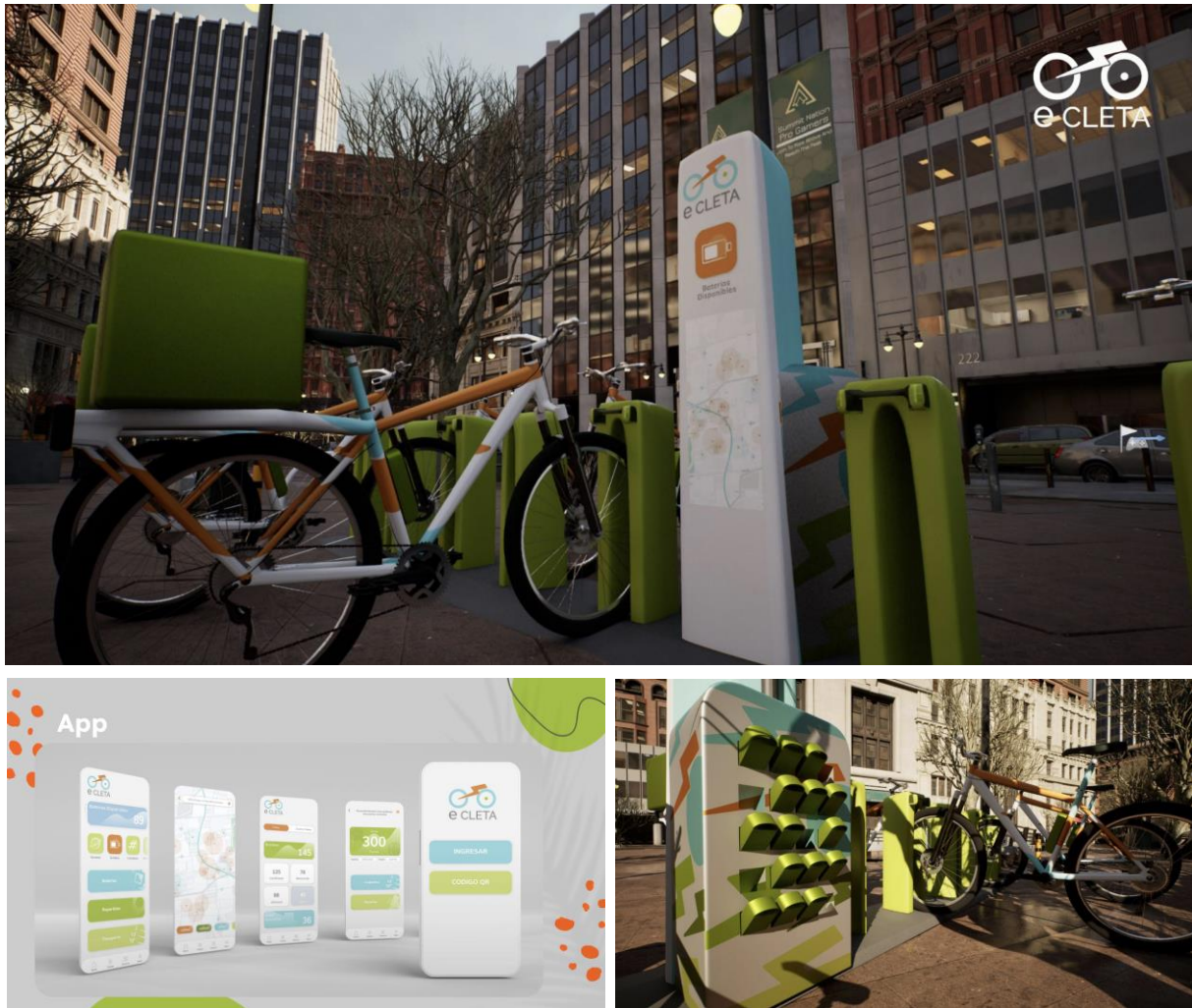
FIGURE 7. eCLETA urban electric mobility system. eCLETA offers an integrated service for alternative electric mobility connected to the public transport system. It includes an app that facilitates bike stations with recharged batteries.

3. Not water: Each drop counts

The purpose of the solution displayed in Figure 7 is to help users avoid wasting water by providing a kit with essential water-saving devices to make saving behaviours tangible. The kit consists of a dripper that detects leaks, an aerator, a saving shower, a Spotify list, a false fill device for the toilet tank, and a water collector that recovers the lost water while waiting for the shower to heat up. Although each device works individually, the kit unifies its identity to work as a 'product' and visually represents the essence of the Not Water project. Having these devices installed in the house gives the users a materialised intervention that is indeed fulfilling the work of saving water in their homes.

FIGURE 8. Not Water, water saving system. This system provides households with tangible elements to install in their homes and save water and an informative webpage for the community.

4. Teduco: Conscious education about children's clothing

Teduco is an educational program around the sustainable use of baby clothes from 0 to 1 year of life for all potential stakeholders (family, friends, parents, etc.) – with the support of a web platform (mock-up in Figure 9) that displays local projects and enables the sharing of content to encourage users to learn and participate. Teduco incorporates a sustainable perspective through concrete actions.

FIGURE 9. Teduco is an educational program that aims to transfer knowledge and encourage parents and families to rethink their behaviours regarding the consumption of baby clothes.

To review the design process of the groups, we arranged this part of the results by organising the patterns found in the analysed documents for each of the four phases of The Compass and using examples to illustrate them.

Prepare Phase

Going through this phase, the groups agreed that taking a closer look at the information and relating the variables implied in the problem gave them new insights into the causes and implications of the situations they were interested in exploring. *Open Space* was a valuable technique to explore the topics of interest, and *Mindmapping and Focus* helped the students acknowledge relations between themes and sub-themes influencing their challenges.

Corroborating previous knowledge

Most groups gathered information that enabled them to corroborate some of their assumptions about the topics they explored. For example, group 1 (DIPP) found that the most significant impact on mental health during the coronavirus pandemic in Chile was related to people's available space in their homes. These led them to research the consequences of confinement during the coronavirus pandemic about the size of homes. By relating the data, they found that Chileans felt 'overwhelmed' by a combination of feeling 'overcrowded' and 'isolated' at the same time. Through this phase, the group realised that space availability affected users in various relevant ways, not only in terms of square meters.

Relating different types of valuable information to understanding problems

During this phase, we observed that some groups gathered information from informal sources to understand the problem from the user's perspective. Group 2 (eCLETA) approached their research by looking at notes or chronicles in the press, interviews on urban issues, and a collection of tweets as a semi-anecdotal source of information. They found that for traditional cyclists, 'mosquito bicycles' are a genuine discomfort for various reasons: they speed on the bike paths, emit gases that are harmful to health, and threaten the safety of cyclists, including other mosquito bike drivers. After that initial data collection, they combined it with more formal studies. They found that the delivery market increased 175% from 2020 to 2021. Among the most used by delivery people were the 'mosquito bicycles', which efficiently increase productivity, accessing them at a low price.

Using information to reflect on problems and perspectives

Group 3 (NOT WATER) declared that during this phase, they discussed and reflected as a team based on needs, problems and opportunities raised around the water crisis. The Prepare phase was also a moment in which the groups could acknowledge issues and perspectives about them by revising and contrasting information. For example, they found that Chile is currently designated as 'high water stress', positioning itself as the first country in Latin America in this condition. In contrast to this reality, they found information regarding the overuse of water in high-income neighbourhoods and the lack of information about the consequences of overuse for the rest of the population.

By reviewing each group's work during the Prepare phase, we observed that gathering information from various sources and by professionals of very different backgrounds enriched the understanding of the challenges. To a greater or lesser extent, and supported by visual tools such as mind maps, each group could identify the main variables implied in the problem they were analysing and their connections. Nevertheless, there was a vast difference in the depth of the research by the groups and in the degree of divergent thinking they showed during this initial phase. For example, group 3 (NOT WATER) researched abundant sources and found unexpected information, while group 4 (TEDUCO) searched for the information they needed to support an initial solution idea.

Perceive Phase

Working in the Perceive phase was motivating for the participants. Going to real contexts to observe and interview possible users gave them a fast connection to the reality of the problems being studied.

Defining and understanding real users

Using *Personas* to organise the information collected about users was an active exercise to visualise peoples' lives and realities. For example, Group 2 (eCLETA) defined users in this phase by directly talking to mosquito bike users and gathering field data. They found out that the highest percentage are men, mainly Chileans and Venezuelans nationwide, who work around 8 hours daily, and delivery services are generally their only source of income. The group could see the problem from a different perspective by conducting this type of enquiry. Group 4 (TEDUCO) researched their possible users using a survey directed to young parents who had children in the last two years. Among the responses obtained, 93.8% bought new clothes before their babies' birth, 87.6% bought clothes between 6 and 12 months before birth, and 37.5% of the total people surveyed kept their clothes in storage for the future after their cycle of use. Therefore, they could confirm that there was a problem regarding the accumulation cycle of baby garments that they needed to untangle.

Questioning assumptions and deepening research to provoke suited solutions.

The Perceive phase is also the moment to evidence missing data in the research and find new information using the *Knowledge Map*. This technique is intended to question the data gathered until that moment and the previous assumptions that need to be explored. Questioning what we know, what we think we know, what we need to know and whom we will ask, both about the challenge and the target users, focalises the areas in which more data is needed.

The groups went back to the context of their problem to observe and ask people about the information they were assuming without having accurate data. This process narrowed user definition to a specific group of people in a particular context, replacing some assumptions with accurate information. For example, Group 1 (DIPP) talked to possible users about their needs and wants regarding space in their homes. Their report's user description was:

> Families of 4 or more members living together, where generally two are minors attending school. The interior spaces of their homes are not delimited and are used for multipurpose activities. They reside in social housing or spaces equal to or less than 40 m2. Their household income corresponds to the minimum salary in Chile. They are people who lack green areas and places to recreate and use public transportation daily to attend their jobs.

The group declared that:

> In the Perceive phase, we did a true refresh of the information and data, which made us think not only about the problem; but to look at it holistically; the users' geography, where they circulate, what they do, their features and characteristics, what motivates them, how space affects them, their main aspirations, etc.

Group 2 (eCLETA) explained that in the Perceive phase, they aimed to use *Personas* to characterise their users in detail and be empathetic with their reality:

> The purpose was to understand who was the user of this means of transport beyond numbers, think of an immigrant with limited resources, the mosquito bike is handy to increase his economic gains since its acquisition price is lower compared to other vehicles, fuel consumption is also very convenient, increasing the number of deliveries significantly if we compare it with a traditional bicycle.

Group 3 (NOT WATER) discovered that people need to perceive water use better. Therefore, there is no awareness of how much is spent nor what the optimal consumption should be. There are no effective incentives to change communities' consumption behaviour, which leads to inactive attitudes in pursuit of caring for a shared resource. In their report, the group explains that through a survey of a larger group of people, they discovered that many ignored that there are domestic devices that alter water flows to reduce its expenditure without affecting its function or performance. They found that people do not use methods or technologies to save water due to a lack of interest or not noticing a significant benefit

in investing in them. On the other hand, research in water companies uncovered that water leaks generate large amounts of water waste that is sometimes not detected in time, generating an incomprehensible expense for the user.

Prototype Phase

The prototyping phase was an active and inspiring moment of the design process for all the groups. Collaboration among peers and team members stimulated idea production and iteration between possible solutions.

Iterating between problem and solution

As in other design methods, iterating between the problem and the solution by fast visualisation and testing possible solutions was fundamental in this phase. Group 1 (DIPP) explained that their solution became more specific as they discussed it and received feedback from the rest of the groups. They prototyped a simple, easily accessible solution to deliver concrete information and essential data to users. In students' words

> We thought of an application that can provide specific solutions for space use, advise on optimisation of spaces, provide furniture options according to M2 of the housing, assembly and design plans, and data about furniture makers.

The idea is based on creating a network of support to improve the quality of life of people and offer them better designed, suitable and enhanced spaces. Why an app? "Because today we know that 68% of the world population has a smartphone and uses it for most of their activities, it is reachable by many audiences to improve the quality of life of thousands".

Thinking through making

Group 2 (eCLETA) was incredibly productive during the prototype phase, generating a series of solution ideas and models through organising and reorganising data to obtain more details on the relation between the different parts of the problem and areas of intervention they could include. Using various ideation and fast prototyping techniques enhanced the creative process of the groups and the definition of their solutions. They explained that in the *Talking Waterfall*:

> The ideas about the problem are deepened without presenting opposition to the speaker that precedes us, forcing us to pay attention to all the group members and avoid conflicts or disqualification of ideas; it is a process of opening or divergence with which many ideas can be covered in parallel.

In their own words, the *Oracle Round* enabled them to obtain: "fresh ideas from the entire class group". They experienced this technique as a:

> high-speed exercise that kindly presses the person who fulfils the function of oracle to deliver quick answers in a limited time, very valuable to broaden the vision on the problem and its possible solutions. In this case, we were very interested in the viability and sustainability of our solution hypothesis since it involved public funds, and it would be ideal if it were as self-sustaining as possible.

After the prototyping phase, Group 2's solution evolved from replacing mosquito bikes with electric bikes to supporting an integrated transport system to decarbonise the city. The group explained that their solution proposal evolved:

> [...] because at first, we had vague data about the end user of the mosquito bikes; we changed the form, impact and context, and we identified that there is a need for more ecological and accessible transport to users who require moving through the city and not just the delivery couriers.

Group 3 (NOT WATER) focused on defining their objectives clearly during the prototype phase. They decided to create a collaborative network that connects, relates to, and involves people at the local level through social networks that allow the sharing of consumer data to generate healthy competition in the optimisation of the use of water resources in the communities. In addition, they considered distributing a water-saving kit of domestic devices to provide users with an easy and economical saving solution in the face of water shortages and to materialise their saving behaviours through them. The group projected a low-resolution MVP during the course and tested it among the community to gain clarity and make informed decisions.

Group 4 (TEDUCO) had a very clear idea of their solution since the beginning of the design process, which underwent minor modifications during the prototype phase. Their final report did not deepen on this stage or their decision-making process using the techniques proposed.

Produce Phase
The Produce phase in this course focused on reflecting on the design process groups had gone through using The Compass. Some extracts of their final reflections during the Produce phase are presented below:

Group 1 (DIPP) reflected on their result and commented:

Now finishing our report, we have realised that we cannot advance ignoring the environment, geography, where our user is inserted, look carefully at the context, have accurate information; data, analysis, surveys, studies, interviews etc. Look at our user thoroughly and not only a part of it.

Group 3 (NOT WATER) concluded that: Without the knowledge of what happens in our environment, we are passive actors of our city, not generating any change for the common good. With information and support, we can move to change habits. They reflected on the power of making information available to promote behaviour change towards a sustainable lifestyle. Lastly, as the group tested their prototype with real users, they could observe reactions that guided their design decisions: "When users discover that they consume more or less water than their peers, and they did not imagine that their consumption was out of the ordinary, they are motivated to change their habits".

Group 4 (TEDUCO) reflected on how The Compass helped them to objectify their observations and views about the problematic situation they wanted to address: "Thanks to this method, we were able to navigate our prejudices about users and the existing solutions".

DISCUSSION AND CONCLUSIONS
Reviewing The Compass approach to solving complex challenges in interdisciplinary teams is a first step to understanding its potential as a collaborative human-centred design approach for sustainability. The study's outcomes add empirical evidence to exemplify how this approach structures the collaborative design process and mobilises action. Nevertheless, we found a need to incorporate specific methods for sustainable design to assess design decisions and proposed solutions during project development.

During the Prepare phase, all the groups gathered information that helped them understand their study topic. However, we identified that although finding a variety of information is useful, not knowing which relevant information is necessary to consider the sustainability issues of each case may be misleading or biased.

The Perceive phase was a turning point for most participants, as they could acknowledge the problem from the users' perspective. The sequence of developing *Personas* and *Knowledge Maps* was fruitful, as questioning what we know, what we think we know, and what we need to know oriented the projects towards narrowing down to a specific group of people affected by a particular issue in each context. Iterating between the Perceive and Prototype phases enhances reflection about how the design solution can improve the lives of those involved.

The combination of techniques suggested by The Compass used during the Prototype phase mixed creative and divergent thinking to ideate freely while fostering peer collaboration and listening

to others' perspectives. It is an active and playful part of the process. Adding some specific instruments to assess the sustainability potential of the developing solutions could help to evaluate the feasibility of the ideas.

During the Produce phase, groups reflected together on their design processes using The Compass. Some highlighted ideas were the importance of actively researching the users' environment to focus on their actual needs, the utility of testing early prototypes with real users, and how the process objectified their observations and views about the challenge.

A significant question arose through our data analysis process: Are the results achieved by the interdisciplinary teams pointing in the right direction towards sustainability? This question raises the need to define sustainability in the framework of The Compass and necessarily revise this understanding over time, as it is an evolving concept. We can affirm that The Compass incorporates the concern about creating sustainable solutions that are economically, environmentally, and socially sustainable, which is coherent with the systemic approach of the United Nations report *Our Common Future* (UN, 1987) suggested decades ago.

A stronger connection with the concept of ecological literacy in the principles that drive The Compass could help educators transfer an essential foundational concept that is not yet considered. It is also worth considering the master's programme to reflect on the courses that should be dictated before, during and after the Innovation Through Design course. The dispositional approach described by Koyama and Watanabe (2023) could also be incorporated into the pedagogical standpoint to transfer methods such as The Compass to students from diverse backgrounds. Likewise, introducing the five statements by Micklethwaite (2022) in The Compass could strengthen and update the general sustainability statement presented today in the teacher's guide. Finally, the detailed work developed to map the evolution of design for sustainability and its transitions (Ceschin & Gaziulusoy, 2018; Gaziulusoy & Öztekin, 2018) is necessary as a context to understand the fluidity of the concept of sustainability and as a background to consider the specific methods needed to complement the framework of The Compass which is generic.

Regarding the evaluation of design solutions, even when the triad of Form, Impact and Context is fundamental to assess the coherence of a design solution, it is only presented as a general evaluation for professionals. The Index Project declares that The Compass can be combined and complemented with other methods to develop sustainable solutions. As reviewed in the first section of this article, many of the design methods for sustainability overlap in their standpoints (Ceschin et al., 2016), come from different areas of knowledge and differ in addressing sustainability's economic, environmental, or social aspects. Therefore, future research could focus on exploring other methods in the framework of The Compass, which is not yet mentioned in the INDEX Design to Improve Life Teacher´s Guide (2012). This could support the adoption of sustainable approaches in design (Andrews, 2015) and other fields. As is usual of exploratory case studies, results respond to the particularities of the context and are not intended to define generalised conclusions. The replication of the study is complex due to the highly spontaneous interactions that take place between participants and facilitators during working sessions. The Compass includes facilitation techniques intended to keep the creative energy flowing, which are used depending on the functioning of every group. Therefore, the facilitators' experience influences the results to some extent.

Although The Compass has been used since 2012 in Denmark's educational, business, and public institutions, its applicability has yet to be studied. We considered it necessary to inquire about how it contributes to the design process of interdisciplinary teams in the context of a Master of Design and Sustainable Innovation program in Chile. This study is a starting point to deepen the approach's understanding, further development, and potential to address the complexity and specificity of the design solutions that arise. Studies could include more participants and a more extended study period.

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