Design thinking for prototyping and product development within a university-led SMEs cluster initiatives in Bolivia

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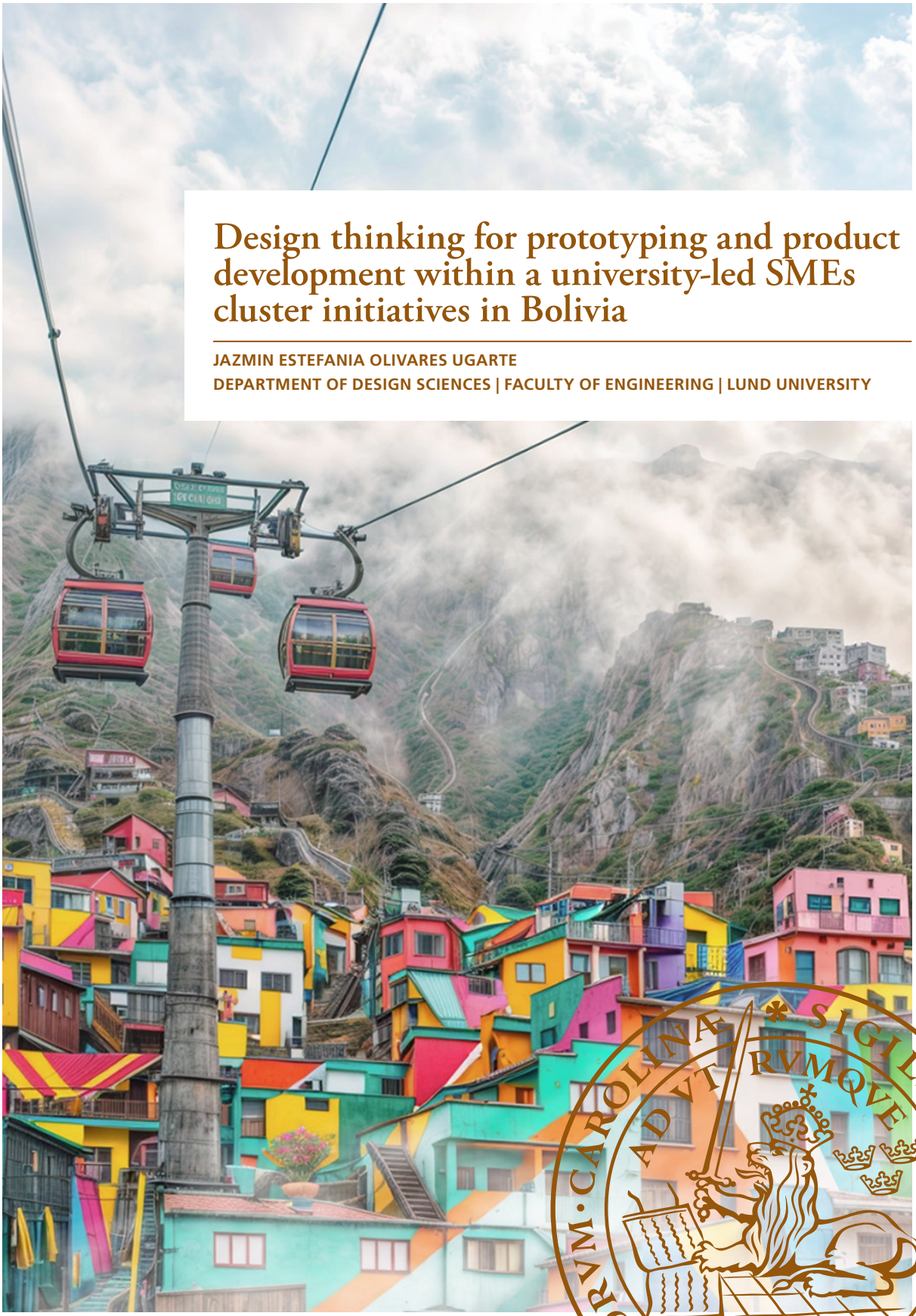

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Jazmin Estefania Olivares Ugarte

LUND UNIVERSITY

LICENTIATE THESIS

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Title and subtitle: Design Thinking for prototyping and product development within a university-led SMEs cluster initiatives in Bolivia.

Abstract:

This thesis addresses the critical issue of design and development of products like production machines for SMEs and rural communities as an essential capability to foster local technology development within the innovation systems of Latin America. What is studied and discussed in this thesis is the pre-requisites for effective application of design and development methods, like design thinking for prototyping and industrial production machinery, in collaborative spaces of universities and small and medium enterprises (SMEs) in the Bolivian context. For this purpose, the theoretical and empirical perspectives of central characteristics and critical success factors for design thinking implementation for prototyping and product development for SMEs clusters are studied and evaluated. The SME cluster initiatives are facilitated by a public university, which follows the mission of a developmental university through the democratization of knowledge, with one of its principal activities being the design and development of products like industrial production machines. The adoption of design thinking approaches and methods has been introduced as a new tool in the supporting activities between university-industry, to strengthen the SMEs' and rural communities' capabilities to design, prototype and develop new industrial production machines and new agricultural production methods.

This research-based framework may facilitate the SME managers' understanding of how it works and how it can be applied successfully, which is particularly valuable for resource-constrained SMEs. The framework shows central characteristics of design thinking implementation like dimensions of critical factors, strategies, tools, and phases. Based on the identification of the critical factors some strategies emerged to improve the development of prototypes and machines like the use of visualization tools, such as customer journey maps within SMEs cluster initiatives context. This tool inspires and promotes communication with users and stakeholders, to get a deeper understanding of user needs. This facilitates the achievement of more satisfactory results of feasible, viable and sustainable machine projects that are appropriate to the capabilities of users/clients. In resume, this thesis elucidates some issues on how facilitate the implementation of design thinking for prototyping and product development. It further explores how this approach can contribute to addressing problems within the context of university-led cluster initiatives involving SMEs and farmers with limited resources. This evidence underscores the broad applicability of design thinking approach and highlights the extensive potential for further research into its implementation within this specific context.

Key words: Design thinking, prototyping, developmental university, cluster initiatives, small and medium enterprises, critical success factors.

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This thesis is dedicated to all people who were part of this beautiful experience.

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Abstract

This thesis addresses the critical issue of design and development of products like production machines for SMEs and rural communities as an essential capability to foster local technology development within the innovation systems of Latin America. What is studied and discussed in this thesis is the pre-requisites for effective application of design and development methods, like design thinking for prototyping and industrial production machinery, in collaborative spaces of universities and small and medium enterprises (SMEs) in the Bolivian context. For this purpose, the theoretical and empirical perspectives of central characteristics and critical success factors for design thinking implementation for prototyping and product development for SMEs clusters are studied and evaluated. The SME cluster initiatives are facilitated by a public university, which follows the mission of a developmental university through the democratization of knowledge, with one of its principal activities being the design and development of products like industrial production machines. The adoption of design thinking approaches and methods has been introduced as a new tool in the supporting activities between university-industry, to strengthen the SMEs' and rural communities' capabilities to design, prototype and develop new industrial production machines and new agricultural production methods.

This research-based framework may facilitate the SME managers' understanding of how it works and how it can be applied successfully, which is particularly valuable for resource-constrained SMEs. The framework shows central characteristics of design thinking implementation like dimensions of critical factors, strategies, tools, and phases. Based on the identification of the critical factors some strategies emerged to improve the development of prototypes and machines like the use of visualization tools, such as customer journey maps within SMEs cluster initiatives context. This tool inspires and promotes communication with users and stakeholders, to get a deeper understanding of user needs. This facilitates the achievement of more satisfactory results of feasible, viable and sustainable machine projects that are appropriate to the capabilities of users/clients. In resume, this thesis elucidates some issues on how facilitate the implementation of design thinking for prototyping and product development. It further explores how this approach can contribute to addressing problems within the context of university-led cluster initiatives involving SMEs and farmers with limited resources. This evidence underscores the broad applicability of design thinking approach and highlights the extensive potential for further research into its implementation within this specific context.

Resumen

Esta tesis aborda el tema crítico del diseño y desarrollo de productos como máquinas de producción para PYMEs y comunidades rurales como una capacidad esencial para fomentar el desarrollo tecnológico local dentro de los sistemas de innovación de América Latina. Lo que se estudia y discute en esta tesis son los pre-rrequisitos para la aplicación efectiva de métodos de diseño y desarrollo, como el pensamiento de diseño para la creación de prototipos y maquinaria de producción industrial, en espacios colaborativos de universidades y pequeñas y medianas empresas (PYME) en el contexto boliviano. Para ello, se estudian y evalúan las perspectivas teóricas y empíricas de las características centrales y factores críticos de éxito para la implementación del pensamiento de diseño para el prototipado y desarrollo de productos para clusters de PYMES. Las iniciativas de cluster de PYMEs son facilitadas por una universidad pública, que sigue la misión de una universidad de desarrollo a través de la democratización del conocimiento, siendo una de sus principales actividades el diseño y desarrollo de productos como máquinas de producción industrial. La adopción de enfoques y métodos de pensamiento de diseño se ha introducido como una nueva herramienta en las actividades de apoyo entre la universidad y la industria, para fortalecer las capacidades de las PYME y las comunidades rurales para diseñar, crear prototipos y desarrollar nuevas máquinas de producción industrial y nuevos métodos de producción agrícola.

Este marco basado en la investigación puede facilitar a los gestores de las PYME la comprensión de cómo funciona y cómo puede aplicarse con éxito, lo que resulta especialmente valioso para las PYME con recursos limitados. El marco muestra las características centrales de la aplicación del pensamiento de diseño, como las dimensiones de los factores críticos, las estrategias, las herramientas y las fases. A partir de la identificación de los factores críticos surgieron algunas estrategias para mejorar el desarrollo de prototipos y máquinas, como el uso de herramientas de visualización, como los mapas del recorrido del cliente en el contexto de las iniciativas de cluster de las PYME. Esta herramienta inspira y promueve la comunicación con los usuarios y las partes interesadas, para obtener una comprensión más profunda de las necesidades de los usuarios. Esto facilita la obtención de resultados más satisfactorios de proyectos de máquinas factibles, viables y sostenibles que se adecuen a las capacidades de los usuarios/clientes. En resumen, esta tesis dilucida cuestiones sobre cómo facilitar la aplicación del pensamiento de diseño para el desarrollo de prototipos y de productos. Además, explora cómo este enfoque puede contribuir a abordar problemas en el contexto de las iniciativas de clúster dirigidas por la universidad, que involucran a PYMEs y agricultores con recursos limitados. Estas pruebas subrayan la amplia aplicabilidad del enfoque del pensamiento de diseño y ponen de relieve el gran potencial que existe para seguir investigando su aplicación en este contexto específico.

List of Papers

The licentiate thesis includes the following appended papers.

Paper I

Olivares J. and Bengtsson L. (2024) *Central characteristics and critical success factors of design thinking for product development in industrial SMEs*. A bibliometric analysis. Paper under review in the journal *Businesses*

Paper II

Olivares J. and Arandia F. (2023) *Critical factors of Design Thinking Implementation for Design of prototypes for SMEs of Cluster initiatives. Cases from Bolivia*. Paper under review in Latin American Journal Management for Sustainable Development.

Paper III

Olivares J., Paxling L., Acevedo C. and Arandia F. (2024) *Journey maps to improve user involvement in innovation processes. Bolivian case of collective green house prototype*. Paper presented at International Conference on regional development in South America. Empowering knowledge flows and collaboration networks, Montevideo, Uruguay (February 8th of 2024). Paper under review in Journal of Agriculture, Food Systems, and Community Development (JAFSCD).

Author's contribution to the papers

Paper I

Jazmin Olivares assumes the role of the primary author, responsible for producing the majority of the text. Lars Bengtsson contributed by assisting in the formulation of the research design, offering insights for the bibliometric analysis and co-writing and editing of the results, discussion, and conclusion segments.

Paper II

Jazmin Olivares assumes the role of the primary author, responsible for crafting the majority of the text and for the research design, data collection and analysis of the study. Franco Arandia assisted in the data collection phase and reviewing the text. J.O and F.A participated in the study and compiled the theoretical framework used in this paper.

Paper III

Jazmin Olivares was responsible for the research design, data collection, and analysis of the study. She was responsible for producing the majority of the text (including visualisations), edited it, and revised it based on feedback from the co-authors, study participants, and conference reviewers. Linda Paxling contributed by assisting in the formulation of the research design, reviewing the introduction, offering insights and writing the results, discussion, and conclusion segments, as well as meticulously reviewing and enhancing the manuscript at each stage of the research's development. Carlos Acevedo assisted in data collection phase and reviewing the text. Franco Arandia assisted in formal analysis, data curation and conceptualization.

Together with the specific contribution of authors, all papers presented were supported by my supervisor and co-supervisors' guidance, Lars Bengtsson, Linda Paxling, Carlos Acevedo and Eduardo Zambrana.

Abbreviations

CI	Cluster initiatives
DT	Design thinking
CFC	Cochabamba Food Cluster
CIFEMA	Centre for research training and extension in agricultural mechanization
GTC	Green Technology Cluster
PAR	Participatory Action Research
PITA	Program research in applied technologies
PDTF	Program of manufacturing technology development
R&D	Research & Development
SAM	Mixed joint-stock company
SCIAME	Scientific society of applied mechanical and electromechanical engineering
SMEs	Small and medium sized enterprises
TTO	Technology transfer offices
UMSS	Universidad Mayor de San Simón
UTT	Unit of technology transfer

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1. Introduction

This chapter presents the introduction, research problem, aim of the research, research questions, research focus and demarcation and the thesis outline.

1.1 Introduction

Latin-American countries, such as Bolivia, are actively seeking strategies to promote local technological and socio-economic development of productive industrial machinery to enhance the capabilities of small and medium-sized enterprises (SMEs). This is due to two aspects: first, policies to promote imports of equipment and machinery from countries with greater technological development impede the economic growth of developing countries. Second, SMEs are considered the engine for economic development of Latin American countries. Thus, this thesis studies and discusses the pre-requisites for effective application of design and development methods, like design thinking for prototyping and industrial production machinery, in collaborative spaces of universities and small and medium enterprises (SMEs) in the Bolivian context. For this purpose, the theoretical framework and empirical perspectives of central characteristics and critical success factors for design thinking implementation for prototyping and product development for SMEs are studied and evaluated. The SME cluster initiatives are facilitated by a public university, which follows the mission of a developmental university through the democratization of knowledge, where one of its main activities is the prototyping and design and development of industrial production machines for SMEs.

The design and development of industrial production machines within the Latin American context are constrained by the tendency of companies in developing countries to rely on the international procurement of industrial equipment and machinery (Katz, 2007). This reliance inhibits the advancement of local technological development. This is due to common characteristics of emerging innovation systems in Latin America such as the weak demand for knowledge (Arocena & Sutz, 2012) and the challenge of innovating under conditions of scarcity (Srinivas & Sutz, 2008).

Furthermore, the focus of innovation has progressively shifted to being design-driven, customer-centric, and user experience-centric (Naiman, 2019).This has an impact on the logic of interaction skills (Srinivas & Sutz, 2008) where Latin American countries have begun to develop links between companies like SMEs (agricultural or industrial) and the local university apparatus, to promote innovation through the development of technology in each country (Álvarez et al., 2019). This is due the public universities of Latin American countries constitute the main site for the creation of advanced knowledge. They have a great responsibility to make research and innovation powerful levers for sustainable human development (Arocena & Sutz, 2023). By this manner, university participation in innovation systems can foster more inclusive societies.

This research is focused on the case of Bolivia, a Latin American country categorized as a lower-middle-income economy country (The World Bank, 2023). The Bolivian context is characterized as one of the most limited in Latin America to foster innovation, with one of the lowest public and private investments for R&D activities (BTI, 2024; Iriarte & Acevedo, 2020). This has traditionally made technological development in the country dependent on the importation of knowledge. This affects mainly SMEs who do not have the innovation capabilities to develop their own technology, nor the necessary resources to import technology. This is where the need for SMEs to rely on the university arises to increase access to technology and scientific findings addressing among other things poverty-related needs.

Given that context, Bolivia is strengthening endogenous innovation capacities, generating technological innovation policies and promoting university-industry collaboration as fundamentals for the formation of an inclusive innovation system (Iriarte & Acevedo, 2020). Universities can be the test laboratories for adapting and creating new university-based mechanisms to support national innovation system (NIS) strategies, and to further societal goals carefully taking into consideration the local context (Acevedo et al., 2015).

In Bolivia, important efforts are being promoted to connect the public university and their local technological development capabilities with small and medium sized enterprises (SMEs). These connections take the shape of interactive learning spaces, also called SME clusters. This is the case of Universidad Mayor de San Simón (UMSS), one of the biggest public universities of Bolivia, which follows a developmental university approach (Arocena et al., 2017) where the democratization of knowledge is crucial for the development of the innovation system.

Authors like Arocena et al., (2015) describe developmental universities as committed specifically to social inclusion through democratization of knowledge. This means that knowledge generated by different projects is accessible for all stakeholders that allows to answer requirements of various enterprises with similar

necessities for the continuous improvement of projects. Under this umbrella, university bodies like technology transfer offices can play a crucial role leading institutional transformations and linking the university research dynamics with the socio-economic demands (Acevedo et al., 2015).

University's cluster initiative

In the context of Universidad Mayor de San Simon (UMSS), the Unit of Technology Transfer (UTT-UMSS) was created in 2004 with the basis of Innovation Systems Approach to increase the impact of UMSS research activities in local socio-economic development. In 2007 the unit adopted a clustering strategy (joining university, business, and government) to improve university-society collaboration under a systemic approach (Arandia et al., 2020).

The first cluster created in 2008 was the "Food Cluster Cochabamba" to respond the requirements of food sector connecting them with the corresponding research centers oriented to food campus. The newest cluster is the "Green Technology Cluster "created in 2021 with the circular approach as part of their innovation strategy. The registered firms by the year of 2024 are 100 in the Food Cluster and 20 in Green Technology Cluster.

Thus, both spaces were created to respond to the demands requested by the business sector through leveraging the capabilities of research centres, which allows strengthening the university-business relationship (Acevedo, 2018). In these spaces, the university provides support to SMEs in the development of research projects, design of production machines, co-design experiences, food safety, business models and others.

Design of industrial production machines projects for SMEs clusters

By 2007, the Program of Innovation and Technology Transfer (INNOVA) was created at UTT with the aim of fostering innovative capabilities within UMSS research centers to promote the development of local technology to support SMEs and collectives of rural communities through cluster initiatives. Within these clusters, novice designers—students from mechanical or electromechanical fields—undertake machine design projects under the supervision of researchers from UMSS's metal mechanics research centers and UTT facilitators.

After more than a decade, the university has gained valuable insights from facilitating the development of various machines using a participatory action research methodology for inclusive innovation. The industrial production machines developed for SMEs within the food cluster and green technology cluster were scaled and adapted to the enterprises' production processes, despite their limited resources. This challenge led to the adoption of criteria for adaptive and creative

responses (Arandia et al., 2020). These criteria have the potential to drive processes of innovation and technological change (Lepratte et al., 2011).

Design thinking approach appears as a good option for SMEs clusters because of its creative approach to innovation development, and pivotable and profitable principles (Assink, 2006). Previous researchers show the importance of the use of design thinking in SMEs to solve social problems in contexts with limited resources (Aporta, 2023; Lawson & Meijers, 2024) and the challenges involved in its application (Eisenbart et al., 2022; Rösch et al., 2023).

1.2 Research Problem

The experiences from the INNOVA program at UMSS show that support activities for SMEs in university-industry spaces, such as design and development of industrial production machines, do not follow a standardized theoretical model supported by research, rather they follow self-developed models (Olivares, 2020). Outcomes from such support projects frequently exhibit uncertainty and, very often, not fully satisfactory outcomes. Based on two previous studies realized by Arandia et al. (2020) and Olivares & Arévalo (2022) on design projects of industrial production machines have shown that design and development projects with industry are not generating enough satisfactory results for SMEs.

The first study of Olivares & Arévalo (2022) report on the state of the art in the application of the prototyping engineering and prototyping management factors, based on 4 case studies of prototype industrial machinery manufactured by the metal-mechanics research centers of the UMSS. The study aims to determine guidelines for prototyping strategies. The users of these projects are rural communities, non-governmental organizations, and researchers of UMSS, so there are no SMEs involved. The evaluated experiences are summarized in the following Table 1:

Table 1. Details of case studies analysed regarding prototyping engineering and prototyping management factors based on Olivares (2020).

Case Study	Research center	User	Sector
Wheat threshing machine	Program of Manufacturing Technology Development (PDTF)	Rural communities of Chuquisaca city.	Food
Fiber and wool carding machine	Center for Research, Training and Extension in Agricultural Mechanization (CIFEMA UMSS) and CIFEMA SAM (Mixed Joint-Stock Company)	Rural communities of Potosi city.	Waste management and environment
Automated composting system	Program Research in Applied Technologies (PITA)	A non-governmental organization (Swiss contact)	Rural communities
Automated unmanned vehicle for roadside control	Scientific Society of Applied Mechanical and Electromechanical Engineering (SCIAME)	Novice designers and researchers	Transportation and surveillance

The main results of this evaluation were the following:

- UMSS research centers linked to the case studies, conducted the prototyping processes based mainly on accumulation of practical knowledge, based on the experiences of researchers, novice designers, and expert designers. The engineering and prototyping management approaches were reactive rather than systematic and without formal protocols.
- There is an opportunity to match the practical knowledge, accumulated by the research centers, with cutting-edge tools of proven effectiveness such as design thinking, to improve the current engineering and prototyping management processes. This in order to face the challenges of optimizing the installed research capacities of the UMSS and to respond effectively to the demands of technological innovation and of prototyping processes of productive complexes prioritized in Bolivia such as cluster initiatives.

The first study concludes that there is an absence of a formal prototyping strategy that places order and discipline in prototyping processes and showcases the technological capabilities of UMSS research centres (Olivares & Arévalo, 2022).
The second study of Arandia et al. (2020) focuses on analysing the facilitation processes during the design and prototyping process, to identify the core elements and improve their practices. Prototyping processes involving 13 novice designers, 3 expert designers, 8 facilitators, and 10 SMEs managers were analysed. The users in the case studies are SMEs in the Food Cluster Cochabamba. The industrial production machines developed had to meet certain requirements for power transmission mechanisms, as well as the use of stainless-steel materials and other

treatments to comply with food safety regulations. The evaluated experiences are summarized in the following Table 2:

Table 2. Details of case studies focused on analysing the facilitation processes during the design and development machine process based on Arandia et al. (2020).

Case Study	SMEs	Classification	Sector
Bread grinder	BOCO	Small enterprise	cereals and derivatives
Orange washing machine. Orange pre-washing	Frutijugo	Microenterprise type 2	alcoholic beverages fruits
Egg breaker Banana centrifuge	Carolina	Microenterprise type 1	cereals and derivatives
Potato peeler Snack centrifuge	Chiflita	Microenterprise type 2	roots, tubers, and derivatives
Nougat slicer	4 Arroyos	Small enterprise	cereals and derivatives fruits and derivatives
Olive destemmed	Casa Venturini	Microenterprise type 2	Milk and dairy products fruits and derivatives
Fruit mincer	Carblaz	Microenterprise type 1	fruits and derivatives
Cereal mixer	Ceretar	Microenterprise type 2	cereals and derivatives
Pulping machine	Capra SRL	Small enterprise	Fruits
Almond grater	Galletica	Microenterprise type 1	cereals and derivatives

Note: the enterprise classification is based on Supreme Decree No. 3567 of the Plurinational State of Bolivia.

One conclusion from this second study, performed during the period of 2014-2018, shows that the consequences of not having standardized prototyping processes are a too high frequency of non-functional prototypes. The results based on 13 prototypes show seven functional prototypes (54%) that met the needs of the entrepreneurs and 6 prototypes (46%) that did not meet the functional objectives and were part of a slow learning curve (Arandia et al., 2020).

In this manner, the support program started to use design thinking models (Garcia & Dacko, 2015; Naiman, 2019) as a holistic approach that could improve the design of industrial production machines, including requirements related to sustainability. By including design thinking models and methods in the development of production machines and equipment for SMEs, the production processes in the SMEs would achieve better quality, efficacy and safety of people and the environment.

Design thinking emerges as a highly relevant methodology for addressing complex technological as well as social problems in an effective and sustainable manner (Baldassarre et al., 2024; Bender et al., 2020). Through its phases of empathize, define, ideate, prototype and test, this approach allows to deeply understand the needs of communities, generate creative and collaborative solutions, prototype ideas

to validate them with users, and continuously adapt solutions based on real feedback (Siang, 2020). According to Aporta (2023) the particular importance of design thinking in Latin American countries lies in its user-centered approach to generate innovative solutions that help them solve various social challenges such as poverty, poor education, poor health, labour informality and violence.

Design thinking has been applied in a wide variety of contexts. Its versatility and human-centered approach make it indispensable for anyone seeking to address problems creatively and effectively (Garcia, 2024). However, applying design thinking to prototyping and product innovation can be challenging when one has limited resources, such as time, money, or expertise (Lawson & Meijers, 2024). Despite these limitations, the study by Chou & Austin-Breneman (2017) demonstrates that SMEs operating in constrained contexts can achieve more successful product development and promote economically sustainable growth by effectively designing their manufacturing environments within these constraints.

In the case of the SME clusters at UMSS who face this reality, they searched for strategies to improve the prototyping and product development of industrial production machines that would increase their productive capacity. In this search, SMEs found that the university could support the development of prototype design projects, due to its main activity of developing and democratizing local knowledge to provide effective solutions to local problems of society. The solutions for innovation are developed under scarcity conditions (Srinivas & Sutz, 2008) like the conditions of public universities in Latin American countries. This university-industry collaboration to develop prototype projects and industrial machines for small and medium enterprises is reflected in clustering spaces called SMEs clusters.

Despite some prior research of characteristics and critical factors for design thinking implementation (Eisenbart et al., 2022; Rösch et al., 2023) a framework that describes and analyses the pre-requisites of design application is lacking, in particular for country contexts with more limited resources such as Bolivia. Such a framework could facilitate and guide design thinking application in SMEs operating in limited resource contexts.

Furthermore, prior conceptual studies like De Paula et al. (2019) identify critical success factors for design thinking implementation categorized by four dimensions have not been validated by empirical studies for prototyping and product development in any type of context, including limited resource contexts.

The present research aims to contribute with a theoretical framework and empirical studies of central characteristics and critical factors that facilitate the application of design thinking for prototyping and product development in the context of SMEs clusters.

1.3 Aim of the research

The general aim of this licentiate thesis is:

Develop applied knowledge about application of design thinking for prototyping and product development within SMEs cluster initiatives facilitated by a public university in Bolivia.

1.4 Research questions

General Research question

How can design thinking methods be applied or adapted by SMEs in a university-led cluster initiatives to increase effective application of prototyping and product development?

Specific Research questions

1. What are the central characteristics and critical success factors that are needed to facilitate the effective application of design thinking for product development in SMEs?
2. What are the critical factors (success and impeding) of design thinking implementation identified in product design experiences of SMEs in university-led cluster initiatives?
3. How and what design thinking tools can contribute to the development of satisfactory product?

1.5 Research focus and demarcation

The theoretical contribution aims to identify the relevant pre-requisites needed to facilitate the application and implementation of design thinking methods in this type of context. Design thinking studies related to digitalization, arts and humanities, tourism, and education, i.e., services, are not covered in this research. Based on the current state of the literature, the research focus was narrowed down to prototyping for product-and technology development for SMEs. This research explores the SMEs managers and rural community producers' perspectives of prototyping strategy used, based on design thinking approaches, for development of new products in the context of university-industry collaboration spaces. It is necessary

to clarify that rural communities are included in the SMEs clusters as a collective group that attends requirement of agriculture sector. Thus, the thesis design thinking approaches is focused on the firm level perspective. Therefore, it excludes discussion of design thinking studies on macro level, e.g., policy and sectoral contexts. Lastly, it is not the aim of the research to investigate into the complexities of all the prerequisites of design thinking implementation, i.e., principles/mindsets, tools, skills, although these can be part of general characteristics of design thinking. But rather the approach is to focus upon on the critical success factors and strategies of design thinking implementation for SMEs in this particular context.

1.6 Thesis Outline

The thesis is divided into six chapters. Additionally, at the end includes a compiled summary of three appended papers.

Chapter 1 Introduction presents the background and research purpose of this study.

Chapter 2 Empirical context shows the situation of design projects for SMEs facilitated by cluster initiatives.

Chapter 3 Theoretical Framework provides literature of design for innovation and inclusive development, developmental university, prototyping strategy, design thinking for innovation.

Chapter 4 Research Methodology describes the research process, research design, data collection, and data analysis process used in this study. Additionally, the chapter shows the research quality and ethical considerations.

Chapter 5 Summary of appended papers summarizes the appended papers, their findings, and contributions to the thesis.

Chapter 6 Discussions, conclusions, and future research presents a discussion of the papers' contributions to the research purpose. This chapter presents an overview of findings and practical contributions, discussion of findings, the general conclusions, contributions to the literature of design thinking. Likewise, the following are also presented the study's limitations and future research avenues.

2. Empirical context

This chapter presents Bolivian context that shows the situation of design projects for SMEs facilitated by cluster initiatives.

The industrial sector in Bolivia has truly seen limited development. The design and development of products like equipment and machinery for all sectors (agricultural, construction, mining, energy, industry for mass consumption products, etc.) are imported from international suppliers of countries with more advanced technological development, like the United States, Germany, France, the United Kingdom, Japan, and China (International Trade Administration, 2022), However, some domestic efforts for development of equipment and local productive capabilities are being developed to answer the requirements of Bolivian SMEs. Considering that SMEs are currently considered the engine of economic development of nations for their contribution to employment generation, and the reduction of poverty and social inequalities (Alcon Vila, 2022) these efforts are vital for the economic and social development of Bolivia.

2.1 SMEs innovation capacities in Bolivia

The SMEs sector in Bolivia is characterized by high informality, which brings with it a series of limitations such as: lack of effective government support, lack of access to training, lack of financing and lack of credibility (Encinas & Arteaga, 2007). Some of the problems faced by SMEs in Bolivia include: Obstacles to access flexible bank loans, bureaucracy to establish a business, high costs in importing machinery, high costs of production and transformation of raw materials, lack of access to technology to generate added value to production, smuggling and lack of coordination –relationship between the State, private sector and civil society is another major drawback because only isolated efforts are noticed (Espejo, 2016).

This phenomenon significantly influences the innovation capabilities of small and medium-sized enterprises (SMEs), as the majority lack formally established research and development (R&D) departments, despite employing personnel with extensive experience and advanced academic qualifications. Nevertheless, certain SMEs possess design departments, comprising professionals from diverse fields, which form a crucial component of their innovation processes (Iriarte & Acevedo,

2020). These multidisciplinary teams within design departments may substantially enhance the enterprises' innovative potential. In the absence of such departments, SMEs often seek external collaborations with universities or consultants to support their innovation activities like the development of industrial production machines.

Prototyping is an important part of the product development process, especially for the design of the manufacturing systems in SMEs (Chou & Austin-Breneman, 2017). Prototyping often predetermines a substantial portion of resource deployment in development and influences design project success, this promotes to local productive development of SMEs in Bolivia.

The most important characteristics of SMEs are that they develop in a submerged economy (informal activity), have many limitations in terms of competitiveness, and show the fragility and lack of efficiency of public and private policies to support, promote and strengthen entrepreneurial activity. There are several prototyping constraints reported by SME practitioners in a resource-constrained setting. The main constraints are limited access to quality raw materials, limited access to appropriate manufacturing capabilities, availability of finished goods for modification, and limitations of modelling predictions (Chou & Austin-Breneman, 2018).

A key factor in the growth of SMEs is the impulse that universities may give to the entrepreneurial spirit (Encinas & Arteaga, 2007). The joint work of a cohesive and collaborative private sector and a professional and committed public sector is an important complementary element to conduct an entrepreneurial development strategy (Zevallos Vallejos, 2007).

2.2 UMSS SME Cluster initiatives

In Bolivia, important efforts are being promoted to link local technological development capabilities with SMEs through cluster initiatives organized by a public university, as is the case of Universidad Mayor de San Simón (UMSS), through the *Program of Innovation*. At the end of 2007, this program was approved for inclusion in a bilateral university program funded by the Swedish International Development Cooperation Agency (Sida). During the implementation phase, the *UMSS Program of Innovation* received technical support from Sustainability Innovations in Cooperation for Development (SICD) – a network organization with experience of fostering innovation systems and cluster initiatives in several African countries. This partnership enriched the internal university debates and supported the implementation process for bottom-up innovation system initiatives (Acevedo, 2018).

The actions developed from *UMSS Program of innovation* can be interpreted as approaches of 'developmental university'. This approach has a fundamental component in fostering interactive learning processes oriented to innovation to promote the "third role" of university, which consists of 'extension services and cooperation with external actors for problem-solving in general'. This conception search solving the problems faced by the less favoured population through the production of socially inclusive knowledge (Brundenius et al., 2009).

This approach aligns much better with the research activities that the university through the Unit of Technology Transfer is carrying out to increase the impact in local socio-economic development through the Innovation Systems Approach (Acevedo et al., 2015) adopted as part of its vision. Cluster for inclusive development can be a practical alternative in the context of developing countries, to collaborate and make efficient use of the scarce resources available in universities and government programs.

A cluster initiative may be initiated by government or academia or a private sector development agency. In the case of academia, UMSS' cluster initiative can be closely related to the notion of "socially inclusive knowledge production" (Brundenius et al., 2009). This term is used to highlight purposeful action towards knowledge production, with the explicit aim of solving some of the most pressing problems of those 'excluded from common facilities or benefits those others have'.

Lindqvist et al., (2003) defined cluster initiatives as organized efforts to increase the growth and competitiveness of clusters within a region, involving firms, government and/or the research community.

The cluster initiative consists of all the companies and organizations that are linked together – in collaboration or competition –in value creation. The cluster initiative is the conscious attempt to mobilize and organize these actors and resources to make individual companies/firms in the cluster initiative more innovative and competitive (Clusterpedia, 2011).

A decisive factor for the development of the cluster initiative is cluster facilitation, which supports the collective decision-making and collective action of stakeholders in the cluster initiative (Trojer & Rydhagem, 2014). A cluster facilitator is an individual or a set of individuals whose task is to guide and coordinate the various stakeholders, their resources, and activities, to achieve common goals and objectives shaped by the interests of internal and external stakeholders (Ingstrup, 2010; Wardale, 2008).

In that sense, since 2007 the Unit of Technology Transfer (UTT) at UMSS has developed a cluster initiative as a permanent platform of interaction where specific demands (from governments and socio-productive actors) can be articulated to research activities of UMSS, which have synergies with other institutions to meet those demands (Acevedo, 2018).

Within the socio-productive actors, support is especially provided to SMEs, due to the difficulty they have in acquiring ready-to-use solutions from the global market, and they are therefore looking for a more "customized" approach to their knowledge needs.

UMSS created, on the demands requested by the business sector of SMEs in Bolivia, two cluster initiatives: "Food Cluster Cochabamba" and “Green Technology Cluster”.

Food Cluster Cochabamba

The first cluster created in 2008 was the "Food Cluster Cochabamba" because of the traditional importance of food sector and beverage in the Cochabamba city (SITAP-UDAPRO, 2015) and high concentrated of research university resources oriented to food campus and its current relevance it currently has in the Development Regional Agenda (Acevedo et al., 2015).
The objective of the Food Cluster Cochabamba is to combine private and public capabilities to create solutions to specific problems in food SMEs aligned in 7 strategic axes:

- Development of new products and productive processes,
- Research, development, and technological innovation,
- Training in Good manufacturing practices,
- Design and development of machines,
- Physicochemical and microbiological laboratory analyses,
- Food security and technical advice for SENASAG certification,
- and marketing/commercial support.

By 2024 the Food Cluster Cochabamba consisted of 100 SMEs, 15 UMSS research centers, 20 sectoral organizations and an international network of Latin-American and European universities researchers.

Green Technology Cluster

Inspired by the Food Cluster Cochabamba and responding to the explicit request from the leather industry, the “Leather Cluster Cochabamba” was created in late 2008 which changed in 2021 to the “Green Technology Cluster”. This change occurred for the migration of the leather firms from Cochabamba to Santa Cruz city and because of the new emergence firms that started to adopt a circular approach as part of their innovation strategy. The first firms linked to the Green Technology

Cluster appeared because of a program of circularity organized by an incubator in Cochabamba collaborating with UMSS. In the last phase of the program UMSS research centers to provided support to the development of industrial machine prototypes. The objective of the Green Technology Cluster is to promote the cooperation among SMEs of triple impact (social, environmental, and economic), research centers, governmental agents, and organizations to promote the local innovation and international for inclusive and sustainable development.

By 2024, the Green Technology cluster consisted of 20 SMEs, 10 UMSS research centers and an international academic network. The research and support topics covered in this cluster are related to technology innovation, design and development of prototypes, alternative energies, biotechnology, bioprocess, water treatment, new materials manufacturing, circular business models, social entrepreneurship, agroecology, sustainable development and policy design of science, technology, and innovation.

Rural initiative of inclusive innovation

The rural initiative began in 2023 with an experience of inclusive innovation to support rural communities, like the case of a collective greenhouse prototype developed for Santivañez Municipality of Cochabamba city. The experience of the development of this prototype is analysed in paper 3.

The need to develop this technological innovation initiative arises from the productive losses of agroforestry crops due to constant climatic changes and pests, which imply a risk for the food supply and economic income of producers in two rural communities.

2.3 Public university facilitating design projects within SMEs clusters.

In general, public universities face the challenge of developing a more open collaboration dynamic with socio-economic actors, which denotes the existence of a technological gap between research centres and the absorption capacity of the socio-economic sector (SMEs and producers) (Acevedo et al., 2015). Socio economic sector that demands science, technology, and innovation encompasses the society (in general), agricultural producers, indigenous groups, and the industrial sector (public, private, small, medium, and large enterprises) (VCyT, 2013).

The overall mission of UMSS is to reduce this technological gap and strengthen the line of research of industrial development, production, technology, and innovation (Plan 2008-2013). Thus, through the manufacture of prototypes of machinery and

equipment made by the UMSS research centres, it was possible to improve production processes through the adoption of technologies appropriate to the local context (Olivares, 2020). This prototyping activity is complex and requires the intervention of several factors and the participation of all stakeholders (Camburn et al., 2013).

In that sense, UMSS through the two cluster initiatives: Food Cluster Cochabamba and Green Technology Cluster, facilitated the development of industrial machine prototypes supporting SMEs in their innovation activities, e.g., minimizing the cost, increasing productivity, and reducing time to market of their products (Latifi et al., 2021). The SMEs that are part of the clusters overall find that the added value of the prototypes developed in these spaces are greater accessibility, use of technology adapted to their own needs and ease of maintenance of the prototype machine (Arandia & Olivares, 2020).

However, during some 10 years of experience in supporting SMEs' development of prototypes certain difficulties and restrictions in accessing material for fabrication have appeared. Therefore, the adaptation with simpler parts and materials that were easier to purchase and less costly made the process feasible. This type of problem, prototype development with limited resources, we can relate to what Schlecht and Yang call "thinking inside the box", that is, the adaptation of more complex designs in environments with limited resources created from simpler and locally available parts (Schlecht & Yang, 2014). This difficulty prompted the use of adaptive response and creative response criteria. These criteria can drive innovation and technological change processes (Lepratte et al., 2011). The following part describes some specificities of prototypes developed in each cluster.

Design projects facilitation experience for the food cluster

The machines of design projects developed for the food cluster are manufactured with resistance material at corrosion, at frequent use of clean and disinfection agents. The preferred material is inox because of the prerequisites to get the food security certification of SENASAG.

Diverse machines were developed like mixers, cutters, mills, ovens, centrifuges, washing machines for various foods such as fruits, vegetables, cereals, and others. The projects being developed are fruit dehydrator oven, coffee bean sorter and chocolate cutter.

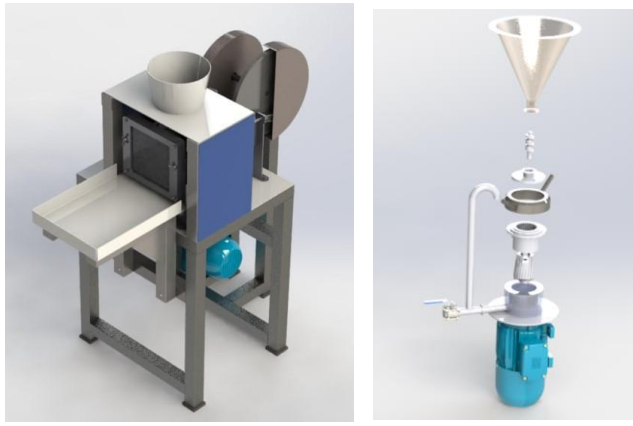

Figure 1. Design projects for the food cluster. Source: UTT (2023)

Design projects facilitation experience for the green technology cluster

The production machines developed in design projects for the green technology cluster are manufactured with common steel material with some heat treatment in some cases to increase its resistance to abrasion, corrosion, and hardness. SMEs of this cluster are starting to search alternatives to create value to the waste from its production processes.

There were experiences of companies that generated new materials such as plastic bags based on organic waste, with which we are currently working on the development of prototypes of machinery. Some projects of machines designed for this cluster are: Dutch Pile, mixer, mixing kettle, pipe forming machine and others.

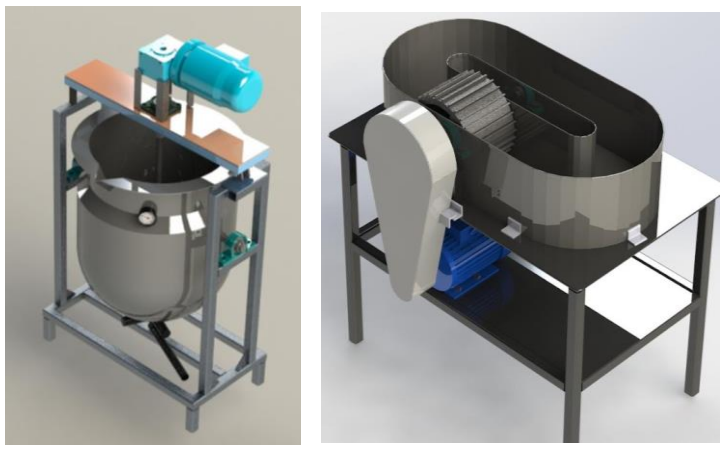

Figure 2. Design projects for the green technology cluster. Source: UTT (2023)

Design projects in the rural initiative

The first experience in the rural initiative was the collective greenhouse prototype structure. This stems from the need to protect the agroforestry production of pests and the effects of climate change in the two communities of Catachilla and Rancho Nuevo that are located in Santivañez municipality of Cochabamba - Bolivia.

This prototype structure will be a learning space for Agroecological Producers (users) “Ecohuertos” families, where they will be able to evaluate and create the adequate conditions for self-sustainable production. The process of design and construction of the greenhouse is based on the use of design thinking methodology, where the participation of local producers is key for innovation processes.

It is necessary to support local producers with technological development, such as for the irrigation system and temperature control, establishing more connection between technology developers (researchers, designers) and local producers, to get solutions that are closely aligned with the needs of the users, i.e., the local producers.

Figure 3. Project of collective greenhouse for Rural initiative. Source: UTT (2023)

3. Theoretical Framework

This chapter presents the theoretical foundation of this research, based on an overview of key concepts related to the research purpose of the thesis.

3.1 Design for Innovation and Inclusive Development

Design is recognized as an important creative process *for innovations and development,* but also with the argument that the design process facilitates the integration of users' and other stakeholders' capabilities and perspectives when developing new solutions (Carlgren et al., 2014; Liedtka J. & Ogilvie T., 2011).

Design for innovation

There is a growing interest for design as a resource for innovation in developing countries and emerging markets.

Innovation is important for the economic and social dynamics and has been placed as a key factor both at firm level and at the country level. Authors like Fagerberg et al., (2005) define innovation as the process that allows combining skills and techniques to provide novel solutions to problems. According to OECD/Eurostat (2018):

"An innovation is the implementation of a new or significantly improved product (good or service), process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations" (OECD/Eurostat, 2018)

Authors like (Arocena et al., 2018) affirm that orienting *innovation* towards more sustainability and less inequality requires deep transformations concerning knowledge and power. Consequently, Latin American countries, including Bolivia, are targeting knowledge-based growth.

Some authors like Aguirre-Bastos (2017) and Aguirre-Bastos et al. (2016) show valuable academic contributions to the process of inclusive development of Bolivia.

Some academic contributions refer to inclusive innovation not only as the process or product that allows satisfying a need of a group of individuals under some type of exclusion but also allows the beneficiary of the innovation to be part of its design and implementation, according to their capacity and resources (Ayala Martínez & Müller, 2017; Edquist & Hommen, 1999; Foster & Heeks, 2013).

The university is considered an important actor in this context, due to its main activity of developing local knowledge to provide effective solutions to local problems of society. In the case of public universities in developing countries the solutions for innovation are developed under scarcity conditions (Srinivas & Sutz, 2008).

This term induced innovations under conditions of scarcity, developed by Srinivas & Sutz (2006) explains that environments differences between developing and industrialized countries lie in the conditions of infrastructure, access to the necessary materials and equipment, institutional support, and sufficiency of qualified personnel available to exploit and develop endogenous capabilities.

Thus, developing knowledge of both innovation systems and the co-evolution of university- society relations in Bolivia is necessary to better guide decisions on resource allocation and to strengthen the articulation of a diversity of society capacities in practical innovation and learning processes.

Design for inclusive development

Design is understood as *development, progress, and improvements* and design thinking is common practice within. It is very often to apply design for product innovation, with design thinking coined as a concept for this (Brown, 2008; Carlgren et al., 2014). The value and role of design thinking for supporting entrepreneurs illustrates how design can support a local network by establishing a co-creation process as the basis for innovations and entrepreneurship in context with limited resources, i.e., the development of inclusive design.

Inclusive design, a user-centred design approach that can be applied when design thinking can assist designers in expanding the boundaries of product usage for as many people as possible by repeatedly adjusting product design to the needs of myriads of users from the start of the design process.

The university may act as an important and neutral actor developing design projects with the participation of all the stakeholders to reach the specific requested requirements of production machines and encourage to inclusive development of the society.

3.2 Developmental university

Brundenius et al. (2009) define the developmental university as one that is open and engaged in interaction with different groups in society, including industry, and whose operations are not guided by profits. Its central aim is to contribute to social and economic development, while at the same time safeguarding a certain degree of autonomy, a concept under which the Bolivian public university system operates, which originated in the so-called Cordoba Manifesto of 1918.

According to Aguirre-Bastos (2017) the key role of the university system in Bolivia is to contribute to inclusive development and social innovations, by contributing to the empowerment of social movements, indigenous communities, and syndicates by responding to their demands through research and high-quality education.

Therefore, the concept of a developmental university is applicable to the context of public universities in developing countries, such as Bolivia, which search solving the problems faced by the less favoured population through the production of socially inclusive knowledge (Brundenius et al., 2009). Authors like Arocena et al. (2015) describe developmental universities as committed specifically to social inclusion through knowledge via three main avenues: democratization of access to higher education; democratization of research agendas; and democratization of knowledge diffusion.

The commitment to the three interconnected missions of developmental universities (1) teaching; (2) research; and (3) fostering the socially valuable use of knowledge, contributes to the production of learning and innovation processes for inclusive development. This gives them the power to determine how the various university bodies interact and contribute broadly to society.

Thus, the case of technology transfer offices (TTO) of university entities plays a pivotal role in aligning the university's research activities with socio-economic demands.

In the context of Universidad Mayor de San Simon (UMSS), a major public university of Bolivia, the research initiatives of the Unit of Technology Transfer (UTT) adopted as a basis the developmental university approach to increase the impact of UMSS research activities in local socio-economic development.

In that sense, since 2007 the UTT-UMSS has adopted a clustering strategy as a permanent platform of interaction where specific demands (from governments and socio-economic actors) can be articulated to research activities which have synergies with other institutions to meet those demands (Acevedo, 2018).

Within the socio-productive actors, support is especially provided to Small and Medium Sized Enterprises (SMEs), due to the difficulty they have in acquiring

ready-to-use solutions from the global market, and they are therefore looking for a more "customized" approach to their knowledge needs.

3.3 Prototyping strategy

Prototyping is an important part of the *product development* process, especially for the design of the manufacturing systems in small-to-medium enterprises (SMEs) (Chou & Austin-Breneman, 2017). Less industrialized economies such the case of SMEs, search different strategies for product development due to unique operating conditions and differences in the user population (Donaldson, 2006). Therefore, the design and prototyping of industrial machines emerges as a need demanded by SMEs to improve the production processes to increase the mass production for generating more incomes. Prototyping is the activity or process which leads to the creation of a prototype.

A prototype is defined as an approximation of the product along one or more dimensions of interest (Ulrich et al., 2020). In turn, it is as a representation of a design that allows us not only the first verification of the future product, but also to be able to be a valuable instrument for the front end of the design. Prototypes are often used to express a concept (Elverum et al., 2014) as a physical or digital embodiment of critical elements in the design, and an iterative tool to enhance communication, enable learning, and inform decision-making at any point in the design process (Lauff et al., 2018).

Ulrich et al. (2020) define concept as a description of the form, function, and characteristics of a product that is usually accompanied by a set of specificities.

Regarding the development of prototypes, Kelley & Littman, 2006 define it as a combination of methods to give physical or visual form to an idea or concept. Other studies of Drezner (1992) and Moe et al. (2004) emphasize that prototyping needs a prototyping strategy. Lack of a prototyping strategy can cause projects to be delayed, go over budget, and therefore the work is not effective (Camburn et al., 2013).

Studies like Chou & Austin-Breneman (2017), addresses the prototype development process in SMEs in constrained context such as: limited access to input variation, restricted access to appropriate manufacturing capabilities, and limitations of modeling predictions. The research results show that firms that effectively design their manufacturing environment within these constraints can enable more successful product development and lead to more economically sustainable development.

In general, a successful project of design and development of prototypes consists of producing a virtual or physical prototype to test the form, function, and technical characteristics of the product, and simulate the cost and service construction. By this manner, the final phase of *prototype product development* results in a manufacturer-ready product design. This includes a pre-production, high-fidelity prototype and detailed specifications the manufacturer will need to begin mass production.

The main idea is to get functional prototypes which involve users at every stage of the design process (Campbell et al., 2007) to ensure compliance with all user requirements. Thus, the systematic integration of user needs in the product design and development is a key issue in industry, especially for SMEs, which often suffer a lack of engineering methods and resources.

3.4 Design thinking origins, frameworks, and practices

Design is an interdisciplinary domain that employs approaches, tools, and thinking skills that help designers devise more and better ideas toward creative solutions (Kelley & Kelley, 2013). The term "design thinking" refers to cognitive processes of design work (Cross, 2011)–or the thinking skills and practices designers use to create new artifacts or ideas and solve problems in practice.

Design thinking can be conceived as a way of framing, reframing, and enacting actions to solve various problems by harmonizing user desirability, economic viability, and technological feasibility (Brown, 2008; Liedtka, 2015; Micheli et al., 2019). Design thinking combines "empathy for the context of a problem, creativity in the generation of insights and solutions, and rationality in analysing and fitting various solutions to the problem context" (Kelley & Kelley, 2013), by inviting the end user/consumer to be a part of the innovation process (Liedtka J. & Ogilvie T., 2011).

Design thinking is emerging in the management literature as a concept that promises innovation through a more user-centred approach which suggests that companies can learn from the way designers think and work (Brown, 2008; R. Martin, 2009). Design thinking matured and is more and more recognized as a strategic instrument beyond product innovation (Knight et al., 2020; Kolko, 2014). As a result, it has been introduced in many different organizational settings, such as SMEs (Acklin, 2010), to solve complex and open-ended problems, like new product development. According to Carlgren et al. (2016), there is a growing interest for design thinking among managers, because the integration of the design thinking process into the SME's product development strategy will improve its competitive position (Best, 2006). However, the integration of design thinking into the product development process can be approached in various ways. To fully comprehend the potential benefits of design thinking for product development, it is essential to understand the

different manifestations of design thinking. Scholars have identified three primary forms of applying design thinking: as a mindset, as a process, and as a toolbox (Brenner et al., 2016; Wölbling et al., 2012).

When conceptualized as a *mindset*, design thinking is distinguished by several core principles, including an intense focus on both explicit and latent customer and user needs, as well as a strong emphasis on prototyping (Brenner et al., 2016). Nonetheless, it has been contended that applying these principles in isolation—absent a structured framework—can pose significant challenges for novices (Brenner et al., 2016). Therefore, in certain contexts, a structured *process* is considered crucial to facilitate novice understanding of design thinking and its contributions to the product development process.

Innovation phases represent a structured process of design thinking encapsulated in five steps: empathize, define, ideate, prototype and test as stablished by Hasso Plattner Institute of Design at Stanford (d. school) (Henriksen et al., 2017). This model of design thinking has attracted significant attention (Kwon et al., 2021) due to its academic foundations and its application in educational contexts (Dorst, 2011; Framework for Innovation: Design Council's Evolved Double Diamond., 2022). These academic roots facilitate the learning process for a diverse range of stakeholders, including SMEs and large firms, in implementing design thinking.

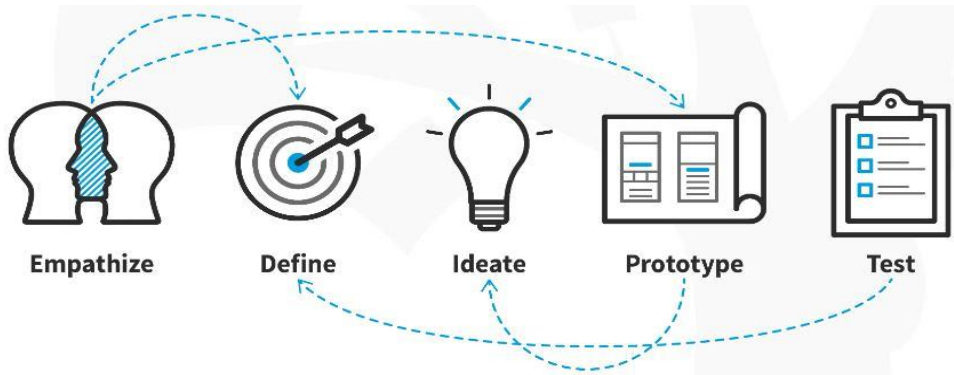

Figure 4. Design Thinking: A 5 Stage process. Source: Interaction-design.org (review in 2023).

With empathy, designers understand users and their actions (Pap et al., 2019). In the definition phase, the collected information is processed, and the challenge is defined (Antoljak & Kosović, 2018). In the ideation phase, rough ideas are developed, while in the prototyping phase, a functional model that helps to verify the design is created (Antoljak & Kosović, 2018; Pap et al., 2019). The last phase is testing in real conditions that can be carried out at all stages of the process and the purpose is to get feedback based on the prototype (Antoljak & Kosović, 2018).

Additionally, design thinking has gained enormous traction over the recent years as an innovation tool (Liedtka, 2017). Thus, various collections of design *tools* exist, catering to both practitioners (Stickdorn et al., 2011) and academics (Hassi & Laakso, 2011). The deployment of appropriate methods is a critical success factor in design thinking projects (Brenner et al., 2016). Therefore, it is important that product development teams possess a thorough understanding of how to apply these methods effectively. Thus, the generation of a research-based framework with the central characteristics and critical success factors of design thinking may facilitate the SME managers' understanding of how it works and how it can be applied successfully. This is especially important for SMEs, with limited financial and other resources. Thus, for SMEs, a creative approach to innovation development, such as design thinking, is even more pivotable and profitable (Assink, 2006). This is because design thinking meets the needs of SMEs in terms of innovation capacity by promoting user- centricity and creativity, as well as uncovering unknown potentials.

While larger companies usually can withstand the consequences of failed product development projects, SMEs have a much lower-level resilience against such failures. Thus, learning lessons from previous product development projects are essential to guide SMEs comprehensively in the application of design thinking into the product development process.

4. Research Methodology

This chapter describes the research methodology and research design employed. Furthermore, this chapter discusses data collection, data analysis and ethical considerations.

4.1 Research Process

The research process has been illustrated in Figure 5. The problem statement explained in Section 1.2 shows the necessity to develop specialized knowledge about design thinking for design and development of products within SMEs clusters.

The research focuses on the construction of a theoretical and practical basis of the design thinking approach and its main features applied in the context of cluster SMEs. Given the wide field of evolution of design thinking, a thorough understanding of the central characteristics and critical factors for its implementation is required to improve the prototyping strategy in the given context.

To meet this need, study 1 consisted of a broader review within the field of design thinking for SMEs, the result of which is shown in Paper 1. Due to the wide range of applications of the design thinking approach, the review was conducted at an early stage. This review, in the form of a systematic search for relevant research and a bibliometric analysis, served as the basis for the subsequent empirical investigations in studies 2 and 3, which resulted in Papers 2 and 3, respectively, limited to design thinking for SMEs. Together, these studies spanned more than two years and addressed all the research objectives. This extensive research effort culminated in this thesis, which summarizes all the research results and contributions to the field of design thinking applied to prototyping and product development for SMEs in resource-constrained countries.

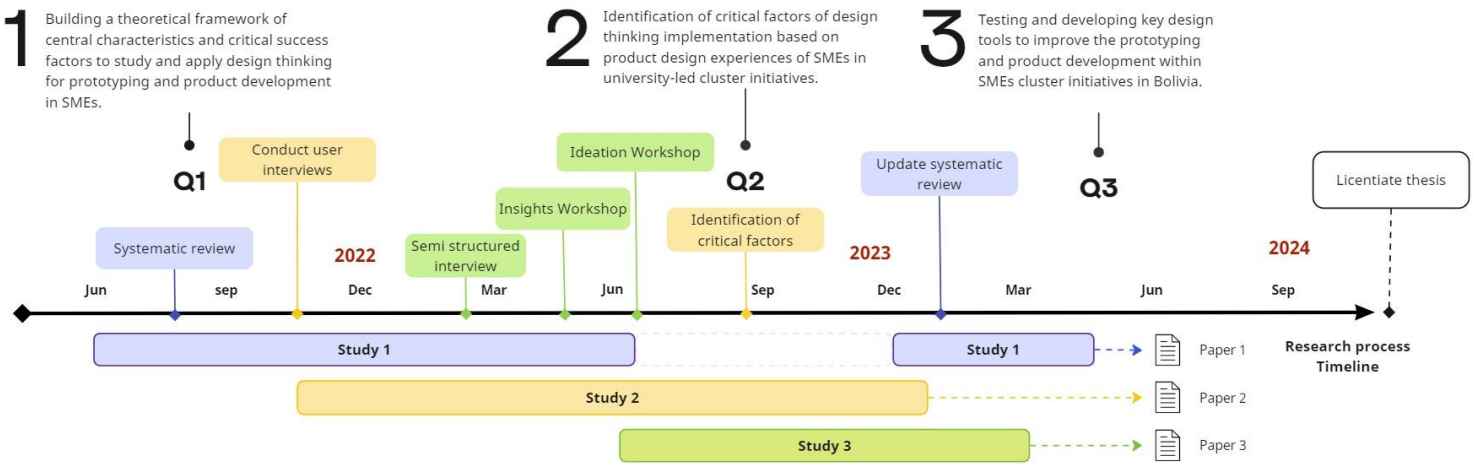

Figure 5. Research process- Timeline. Source: own elaboration (2024)

Figure 6 presents the correlation among the papers developed of theory and practice based on Design Thinking. The figure shows the research questions and research design for each study.

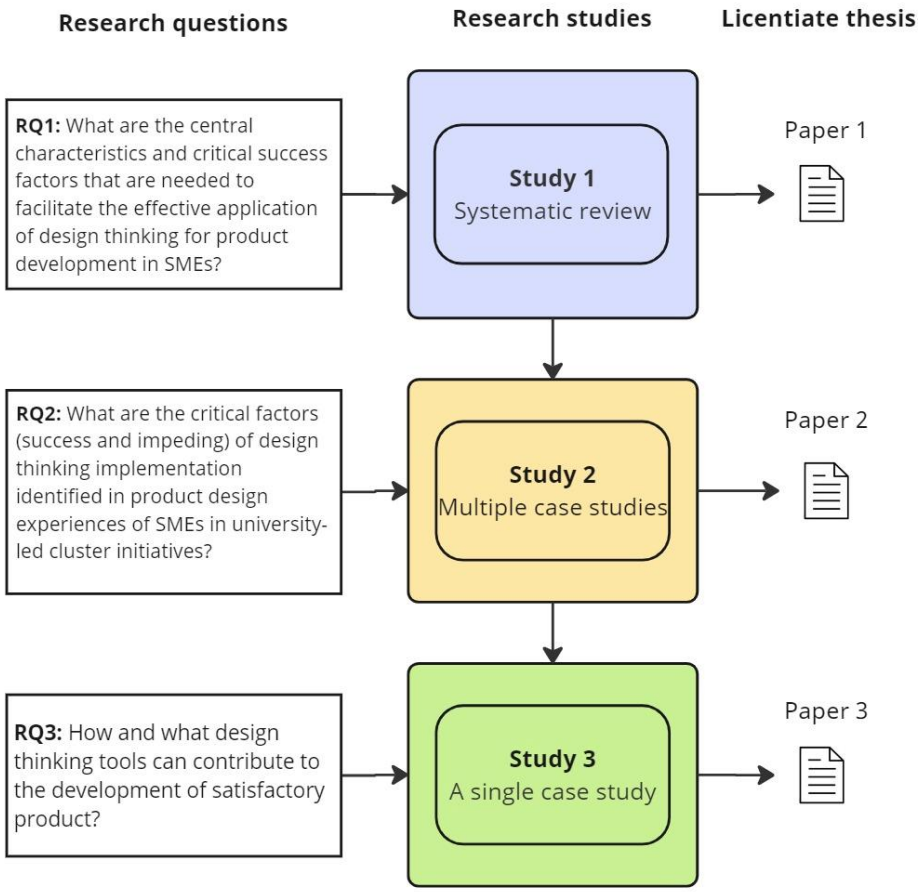

Figure 6. Research process- Research design corresponding to each study. Source: own elaboration (2024)

Participatory Action Research

Participatory Action Research (PAR) researchers recognize the existence of knowledge diversity across a variety of institutions and locations. PAR attempts to embody "a democratic commitment to break the monopoly on who holds knowledge and for whom social research should be undertaken by explicitly collaborating with marginalized or 'vulnerable others'" (Kindon et al., 2015).

PAR highlights the existence of a socially constructed reality, within which multiple interpretations of a single phenomenon are possible by both researchers and participants (Greenwood & Levin, 1998).

This perspective facilitates the translation across various forms of knowledge and knowledge production through methodological innovation, thereby engendering expanded intellectual domains.

Researchers and users, in this case SMEs and producers, identify an issue or situation in need of change. They then initiate research that draws on capabilities and assets to precipitate relevant action. Both researchers and users reflect on, and learn from, this action, which in turn becomes a stepping stone for new cycles of research/action/reflection. This makes the PAR process cyclical (Kindon et al., 2015). Thus, they develop context-specific methods to facilitate these cycles.

McIntyre (2008) explains that the PAR approach is characterized by:

- the active participation of researchers and users (in this case, socio-productive actors, and producers) in the construction of knowledge.
- the promotion of self- and critical awareness leading to individual, collective, and/or social change.
- emphasis on a co-learning process whereby researchers and users plan, implement, and establish a process for disseminating information gathered by the research project.

An integral aspect of these methodologies addressing marginalized or vulnerable demographics lies in their hands-on modality. Equally noteworthy is their capacity to empower individuals to generate information and disseminate knowledge on their own terms, utilizing their unique symbols, language, or artistic expressions (Rydhagen, 2002). Kindon et al. (2007) elucidate how such methodologies diverge from traditional social science paradigms wherein an external researcher dictates the agenda, formulates inquiries, and executes interviews or surveys for subsequent analysis. Conversely, participatory methodologies, now prevalent, underscore collaborative learning, collective knowledge construction, and the necessity of a malleable yet structured joint analysis. These approaches necessitate the researcher to relinquish control (Sense, 2006), positioning themselves as facilitators rather than directors of the investigative process (Wadsworth, 2006). In that sense, the researchers at UTT assume at the same time the role of cluster facilitators. So, they are responsible for coordinating and guiding various stakeholders, managing resources and activities to achieve the design and development of products that meet the interests of all stakeholders. In an environment of informal relationships, it requires the building of trust within cluster relationships, improving the competitive environment among socio-economic actors (Acevedo, 2018).

4.2 Research Design

The research follows a qualitative methodology. The licentiate began with conceptual research with a systematic search for relevant literature and bibliometric analysis to gain understanding of design thinking approach for innovation. Based on that theoretical research, an initial framework with the central characteristics and critical factors to facilitate the effective application of design thinking for product development in SMEs was developed in Study 1.

This starting point gave insights into the success, and impeding factors of design thinking implementation based on design experiences of products projects realized in university-industry collaboration spaces.

Additionally, the diagnosis allows us to identify some strategies to improve product development projects like the use of some design thinking tools. This strategy opens a range of research lines applied to the use of design thinking tools in a context of university-industry collaborative spaces. In that sense, the third empirical paper is focused on the use of one design thinking tool such as journey maps applied for the development of one prototype to support a rural initiative.

Study 1: Systematic search and bibliometric analysis

Study 1 was conducted to identify the central characteristics of design thinking for development of products in the context of SMEs. A systematic search using the search string in Scopus and snowball sampling was realized with the search query of the following keywords "Design thinking" * AND "Innovation" AND (sme* OR smes* OR "small and medium-sized enterprise" OR "small and medium enterprise" OR "small medium enterprise" OR "small and medium-sized firm" OR "small and medium firm" OR "small firm" OR "medium firm" *). The search string included articles, conference papers and book chapters of Engineering or Business, Management and Accounting Subjects areas in English and Germany language. From the analysis of the 30 articles filtered from Scopus and other databases the main findings identify the central characteristics and critical success factors for design thinking application in SMEs. The review process is further detailed in Paper 1 and Figure 7.

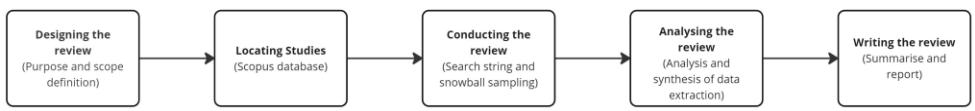

Figure 7. Methodology adopted for Study 1, five step framework proposed by Denyer and Tranfield (2009).

Study 2: Diagnosis paper

Focusing on the critical success factors of design thinking implementation, Study 2 was conducted to identify these factors in design experiences of SMEs in the clusters organized by the university. The aim of this study was to get a diagnosis and some strategies to improve prototyping development projects. Multiple case studies were carried out of 5 prototypes designed for SMEs from which 2 are from green technology cluster and 3 from food cluster. The process is further detailed in Paper 2 and Figure 8.

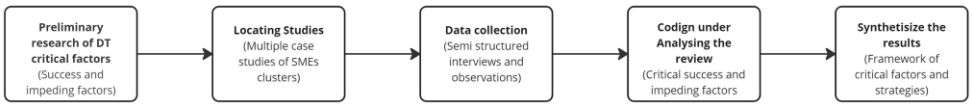

Figure 8. Methodology adopted for Study 2

Study 3: Empirical paper

Study 3 was developed based on one strategy suggested in paper 2 for the improvement of prototyping regarding the use of design thinking tools to foster empathy with users. Study 3 reported in paper 3 was conducted to test the application of one design thinking tool, the user journey map for the development of a prototype. The methodology used was a single case study of a collective greenhouse prototype developed for rural communities. The process is further detailed in Paper 3 and a simplified illustration shown in Figure 9.

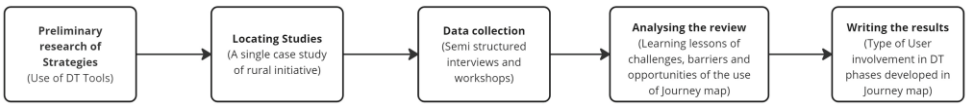

Figure 9. Methodology adopted for Study 3

Table 3. Overview of appended papers for justification of the research design

	Paper 1	Paper 2	Paper 3
Purpose	Building a theoretical framework of central characteristics and critical success factors to study and apply design thinking for prototyping and product development in SMEs.	Identification of critical factors of design thinking implementation based on design experiences of SMEs in university-led cluster initiatives. The aim is to get a diagnosis and strategies of improving the product development.	Testing and developing key design tools to improve the prototyping and product development within SMEs cluster initiatives in Bolivia.
Context	Design thinking characteristics for SMEs	Critical factors of Design thinking implementation	Design thinking tools
Unit of analysis	Design thinking for product development (i.e. prototype product)	SMEs clusters (food cluster and green technology cluster)	Rural communities
Research design	Systematic search and bibliometric analysis	Multiple case study	One case study
Data sources	Literature	Semi-structured interviews, direct observations	Semi-structured interviews, workshops
Data analysis	Bibliometric analysis	Open coding and axial coding	Open coding and axial coding

4.3 Data Collection

Documents and semi-structured interviews were used as data collection techniques for study 2 and study 3.

Documents

Documents were used as data collection technique to have the background of design projects of prototypes in the context of SMEs clusters. Additionally, the documents complement the information provided during the semi-structured interviews with private and public digital materials from their folders in the clusters.

The folders of UTT contain information about history of the creation of this interactive learning spaces, offered services, organizational roles, management models and ways of working.

Every physical folder of SMEs provided information about projects of prototypes developed regarding technical information of prototypes machines, drawings, and 3D software simulations of prototypes.

For the *study 1*, a database with at least 30 scientific documents were collected for the systematic review and bibliometric analysis to get the initial framework with central characteristics and critical success factors of design thinking implementation for product development in SMEs.

Observations

Additionally, observations were used as a data collection technique for the triangulation of information for study 2 and study 3. Due to the methodology used throughout the participatory action research, there is a more active participation of the researchers during the whole process of design and development of the prototypes.

In this case, researcher takes field notes on the behaviour and activities of individuals, these are SMEs managers for study 2 and producers for study 3, at the research site. Observations are open-ended in which the researchers ask general questions to the participants allowing the participants to freely provide their views (Creswell & Creswell, 2017).

Semi- structured interviews

The interview methodology (Brinkmann & Kvale, 2015; Luna & Rodriguez, 2011; Sampieri, 2014) was applied to learn about the challenges and opportunities of prototypes design experiences. The interview is conceived as a process in which, an exchange of ideas, beliefs, meanings, emotions and feelings about experiences, people, groups, and social environments takes place, through the use of words as an essential resource (Bonilla & Rodríguez, 2012; Sandoval, 2002).

Semi-structured interviews were conducted because the provision of flexibility and the better exploration of the key roles' understanding of design thinking (Kallio et al., 2016). Furthermore, semi-structured interview, is a crucial source for case study evidence (Yin, 2018).

For the *study 2*, in-depth semi-structured interviews were conducted with entrepreneurs to examine the reason for the occurrence of something and the impacts of certain design decisions. These allowed to deepen the answers of the interviewees for a deeper understanding for the identification of critical factors of Design thinking. This is due to the follow-up questions on the experiences (positive and negative aspects) in each phase of Design Thinking for the design of prototype projects. SMEs cluster managers of 5 case studies of prototypes designed during

2022 management were interviewed during 3 weeks of November 2022. Of these productive enterprises, 2 are from the food cluster and 3 from the green technology cluster. Of the latter cluster, one enterprise is located in the city of La Paz and the rest is in Cochabamba. Interviews were conducted digitally by videoconference using Zoom with an average length of time of 30 minutes.

For the *study 3*, semi structured interviews and workshops of a deep single case study were developed to obtain the perspective of the other actors i.e., producers, designers, facilitators, and researchers. Producers of 1 case study of a collective greenhouse prototype developed in 2023 were interviewed during one full day of March 2023. Interviews were conducted onsite in a rural community and lasted between 40 to 55 minutes.

Table 4. Overview of Interviews

Case Study	Interviewees	Cluster
Sesame extruder	Manager 1	Food Cluster
Hammer Mill	Manager 2	Food Cluster
Wheatgrass extruder	Manager 3	Food Cluster
Dutch Pile	Manager 4	Green Technology Cluster
Mixer	Manager 5	Green Technology Cluster
Collective Greenhouse	Producers of Catachilla (9 persons) and Rancho Nuevo communities (5 persons)	Rural Initiative

For both studies, interview guides were developed to follow the semi structured questionnaire. Additionally, the interviewee received an informed consent to record the interview, and in which briefly informs them of the objective of the interview and the brief profile of the researcher. According to Kvale & Brinkmann (2009) the informed consent means that informants are aware what the study is about, what role they would play and that they are free to participate or leave the study whenever they choose.

There is a team of three researchers who assumed different roles during the interviews, one of them was the interviewer and the others were the observers. Interview protocols were provided for both to serve as a guide for their interventions and analysis.

All interviews were conducted in Spanish since all interviewees are Spanish speakers and most of them do not speak English. Additionally, they were audio- and video-recorded and transcribed.

4.4 Data Analysis

The data analysis was based on data collected from previously described interviews and documents. Study 1 employs a two-step methodology: first, a systematic search of relevant literature is conducted using a specific search string in the Scopus database, followed by a bibliometric analysis of keywords and abstracts in the selected papers. This approach enables the identification of characteristics and variables associated with the process of applying design thinking (DT) for the development of new products and technologies in small and medium-sized enterprises (SMEs). Bibliometric analysis is recognized as an effective method of summarizing and synthesizing literature (Donthu et al., 2021). The analysis also provides a visualization of the group network derived from the keyword co-occurrence analysis of titles and abstracts in the selected papers.

For study 2, coding was used because it allows synthesizing the information from the general to the particular. Thus, coding is followed in a two-stage cycle, proposed by Tracy, (2020) as (Miles et al., 2014).

These two stages consist first of coding data segments to summarize the content, followed by pattern coding, in which the previous summaries are grouped into concepts, themes or smaller categories.

For this first stage, Excel was used to first code the segments of responses that were identified as success, or impeding factors of the cases studied. In this first coding, the answers were distributed in a double-entry matrix where the success or impeding factors were identified on the one hand, and Dimensions of Design Thinking, on the other hand, are visualized. Considering the existence of fundamental approaches to coding, Miles et al., (2020) presents the four so-called elementary methods, namely descriptive, in vivo, process and concept coding.

For the present research, descriptive codes are used because of the exploratory characteristics pursued by our objective and because this type of code allows assigning a label that summarizes the data segment in a word or short phrase. In this first stage, the codes are characterized by categorizing the data at a relatively general level. Thus, this general first-cycle coding is used as a basis for opening the second-cycle coding.

Secondary cycle coding consists of the organization, synthesis, and categorization of primary cycle codes into interpretive concepts through the use of interpretive creativity and theoretical knowledge (Tracy, 2020).

In this regard, we began to group the segments of responses that approximate some interpretive concepts of a theoretical basis of Success and Impeding factors of the design thinking implementation presented by De Paula et al. (2019).

For study 3 the data collected of interviews and workshops were transcript in journey map template. This study doesn't use codes but uses quotes instead. The quotes of every intervention were organized based on the topics of journey map like needs and pains, thoughts, emotions, opportunities, and area of responsibility.

4.5 Research quality

The criteria to identify the research quality of the study is based on content validity, external validity, and reliability (Säfsten & Gustavsson, 2020; Yin, 2018).

Validation is a quality control that permeates all stages of the research process. It is about testing, questioning and theoretically interpreting the findings throughout the process (Brinkmann & Kvale, 2015).

Content validity

Validity verifies whether the interview study investigates what it intends to investigate. In this case, given the extent of the information collected and the rigorous analysis of the data that had as a basis a theoretical line to identify the existence of the co-design factors, it could be affirmed that the construct validity of this study is high. This is argued by the research of Stuart et al. (2002) who states that the collection of a chain of evidence and the description of the data collection process in detail, allows for this validity.

External validity

External validity refers to the extent findings that can be generalized (Yin, 2018). In this sense, according to (Eisenhardt, 1989) the analytical generality of case study findings can be analysed.

Reflecting on generalizability, according to Brinkmann and Kvale (2015) it refers to whether the findings are primarily of local interest or whether they are transferable to other cases. For this pilot study, we seek to identify success factors and impeding factors of co-design experiences of prototyping industrial production machines developed for small companies with limited resources. In this sense, the findings are linked to a specific context, at a specific time, so the generality of the findings would be given only for cases that are in the same context conditions.

Reliability

Reliability refers to how consistent the results are to consider the replicability of the study (Brinkmann & Kvale, 2015; Yin, 2018). According to a study by Miles et al. (2020) of the criteria for assessing reliability, three were found to relate to whether more than one person has been involved in the data collection/analysis/review. In this particular study my colleague actively participated during the interviews, assuming the role of observer. Likewise, I participated in the verification of the coding of the data and the results obtained. In this sense, I would say that adequate measures were taken to ensure the reliability of the results.

4.6 Ethical considerations

This study considers ethical issues as in practice involves data collection from or about living individuals as the case of managers of SMEs and producers in rural communities.

Before data collection, researchers explain to participants the purpose and the use of data intended to be collected. Additionally, the confidentiality of this research was ensured with the anonymization in transcription of qualitative data collected in interviews and workshops. All these ethical issues are shown in informed consent. After this explanation participants have the right to decide whether to participate in the study.

Before interviewing process or workshop development, researchers asked participants for permission to record the meeting and were given the right to withdraw from the study anytime, they wished. Data processing and results showed are focused on maintaining the confidentiality and anonymity of all participants.

As this research was realized from the context of a public university in which the democratization of knowledge is part of its mission, the owner of intellectual property of all design projects realized by students is the university. In that sense, it exists more viability for data collection of secondary sources as these are saved in the database of different projects realized in the unit of technology transfer (UTT).

4.6.1 Affiliation and conflict of interest.

The present study was funded by the agreement between Lund University in Sweden and the Universidad Mayor de San Simón with the Research Cooperation Programme “Strengthening Research Capacities at Universidad Mayor de San Simon 2021-2025” SIDA Contribution No.13486. The funding is to contribute to advance universal knowledge and develop postgraduate scientific studies to join scientific research, technological development, and innovation activities.

No conflict of interest with respect to the research, authorship and/or publication was identified.

5. Summary of appended papers

This chapter presents a summary of the three appended papers, their findings, and their contributions to the thesis.

5.1 Paper I

Introduction

The evolving industrial landscape increasingly demands multidisciplinary design professionals who can effectively integrate design thinking with engineering expertise in the development of innovative products and services. Design thinking enhances an organization's capacity for innovation (Bonakdar & Gassmann, 2016; B., Martin & Hanington, 2012). Innovation encompasses the exploration of design possibilities, leading to the creation of new products and services, as well as the creative redesign of existing products, thereby adding value for both the company and the end-user. Innovation is widely acknowledged as essential for the survival and growth of small and medium-sized enterprises (SMEs) (Klewitz & Hansen, 2014). Despite their relatively limited financial power and resources, SMEs can thrive by maintaining a strong commitment to innovation in both services and products (De Jong & Marsili, 2006).The rapid advancement of technology has significantly shortened the life cycle of innovative products (Kenney, 2001). Consequently, there is a growing need to adopt holistic strategies to maintain competitiveness and ensure a more sustainable future (Kenney, 2001). The application of design thinking within enterprises enables the identification of key stakeholders and service users (Andreassen et al., 2015) facilitating the conceptualization, prototyping, and development of solutions, as well as improving communication processes (Geissdoerfer et al., 2016). Existing research indicates that large organizations are supportive of design thinking, yet there is a noticeable gap in the literature regarding the successful adoption of design thinking within the long-term strategic management of SMEs (Elsbach & Stigliani, 2018; Micheli et al., 2018). While large organizations continue to integrate design thinking practices, SME leaders face challenges in effectively implementing these processes (Cousins, 2018; Ferrara et al., 2020). This knowledge gap in understanding the specific requirements for applying design thinking in product and technology development

within SMEs underpins the research presented in this paper. The study aims to develop a bibliometric-based framework to better comprehend the prerequisites for implementing design thinking in the product development processes of SMEs.

The question guiding this research is the following:

RQ- What are the central characteristics and critical success factors that are needed to facilitate the effective application of design thinking for product development in industrial SMEs?

The aim is to construct a framework for application of design thinking in SMEs that can provide guidance to SME managers and other stakeholders supporting the development of SMEs, i.e., giving an overview of current research as well identifying the most salient issues in application of design thinking for product development.

Findings

This systematic content analysis seeks to explore the concept of design thinking as it is situated within the findings of the instructional design field, particularly in relation to the development of new products (prototypes) for SMEs. The study presents implications for this field and offers recommendations for the adoption of design thinking practices within it.

The central characteristics of design thinking (DT) application are categorized into four key aspects: principles, criteria, phases, and tools, each of which contributes to the effective implementation of DT in product development within SMEs. Additionally, critical success factors (CSFs) are identified and organized into four dimensions: culture, competencies, strategy, and implementation

Based on these findings, a research-based framework is presented in a visual format, designed in alignment with the principles of design thinking. This framework is intended to function as a visual tool for SME managers and supporting stakeholders in applying DT to their product development initiatives.

Ideas for future research have also been provided.

The ways in which designers conceptualize and apply design thinking are evolving, leading to its adoption across a range of new fields, such as business model development and innovation, digital transformation, and the application of diverse toolbox for product development.

Contribution to thesis

A systematic review and bibliometric analysis will show the central characteristics and critical success factors of design thinking that adjust at SMEs context for an

effective development of product. This main finding will contribute to improve the design strategy of cluster initiatives to get more satisfactory prototypes for SMEs in Bolivia. The findings show the spectrum of design thinking principles/mindsets, criteria, innovation phases, levels of innovation, some tools, and the main critical factors for its implementation. Thus, the figure shows a novel unifying framework for design thinking based on the literature and the context of SMEs.

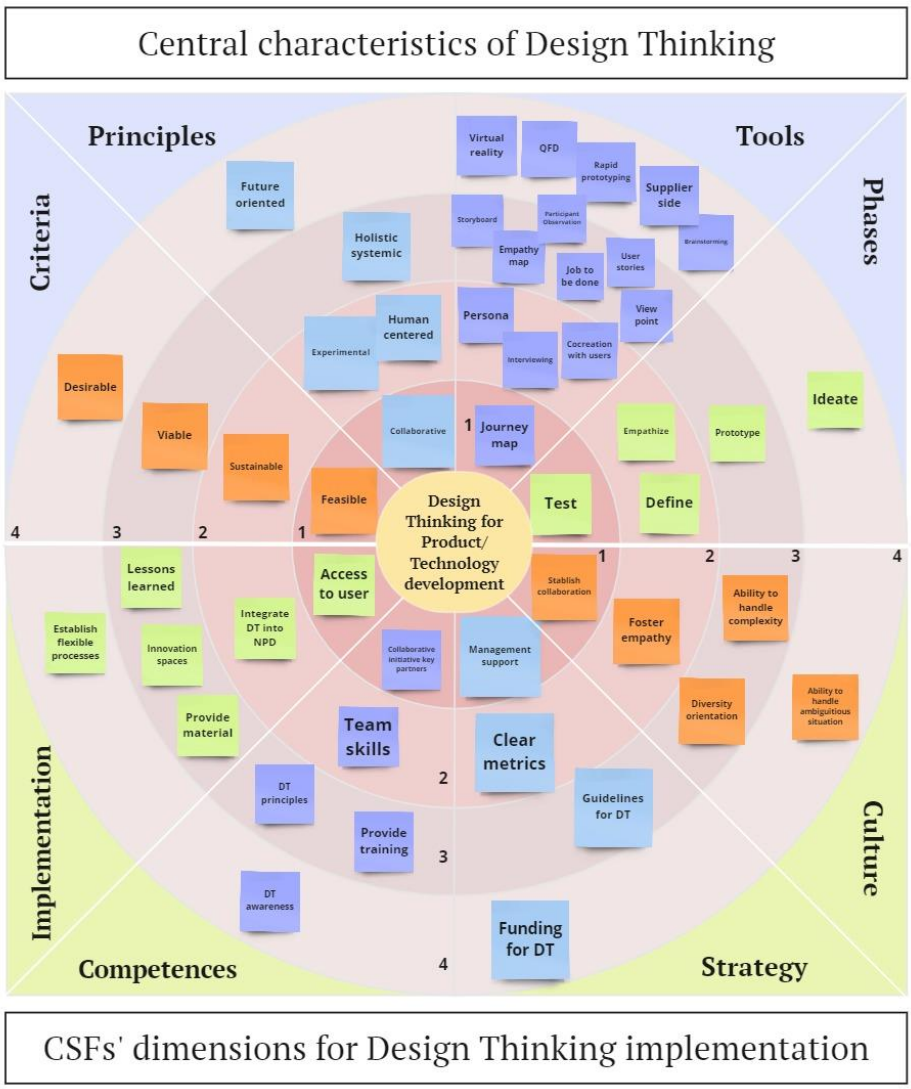

Figure 10. Central characteristics and critical success factors for the implementation of design thinking for SMEs based on the systematic review. Source: Authors' own creation (2024).

5.2 Paper II

Introduction

This research aims to identify the critical factors influencing the implementation of design thinking for prototype development within small and medium-sized enterprises (SMEs) participating in Cluster Initiatives in Bolivia, with the goal of enhancing design solutions facilitated by a public university. The study employs a qualitative methodological approach, utilizing multiple case studies of design experiences to assess the support provided by cluster initiatives to SMEs, based on critical factors for successful DT implementation in technology development. Specifically, the objective of this study is to identify both success and impeding factors in the implementation of design thinking for prototype design within the context of SME cluster initiatives.

The questions guiding this research are the following:

RQ- What are the critical factors (success and impeding) of design thinking implementation identified in product design experiences of SMEs cluster initiatives?

- How can the DT processes be improved based on the critical factors identified in these design experiences of SMEs cluster initiatives?

Findings

The main findings are categorized into factors that either facilitate or impede the implementation of design thinking. The identified success factors include fostering empathy, promoting experimentation and iteration, establishing collaboration and cross-functional teams, and initiating collaborative efforts with key partners. Conversely, the impeding factors comprise time constraints, insufficient management support, and limited resources. Furthermore, strategies for enhancing DT processes include establishing dedicated management functions for design projects, optimizing time management, implementing flexible payment plans, utilizing DT tools, incorporating digital simulation software, and strengthening collaborative efforts.

This research distinguishes as a unique exploration of critical factors of DT in cluster initiatives in lower-middle income economies countries of Latin America like Bolivia. This diagnosis shows the role that universities play in supporting the development of technologies for SMEs, through prototype design projects.

Contribution to thesis

– The implication of this research is based on the identified factors and strategies for implementing design thinking (DT) to improve design projects developed in contexts of university-industry collaborative spaces in developing countries.

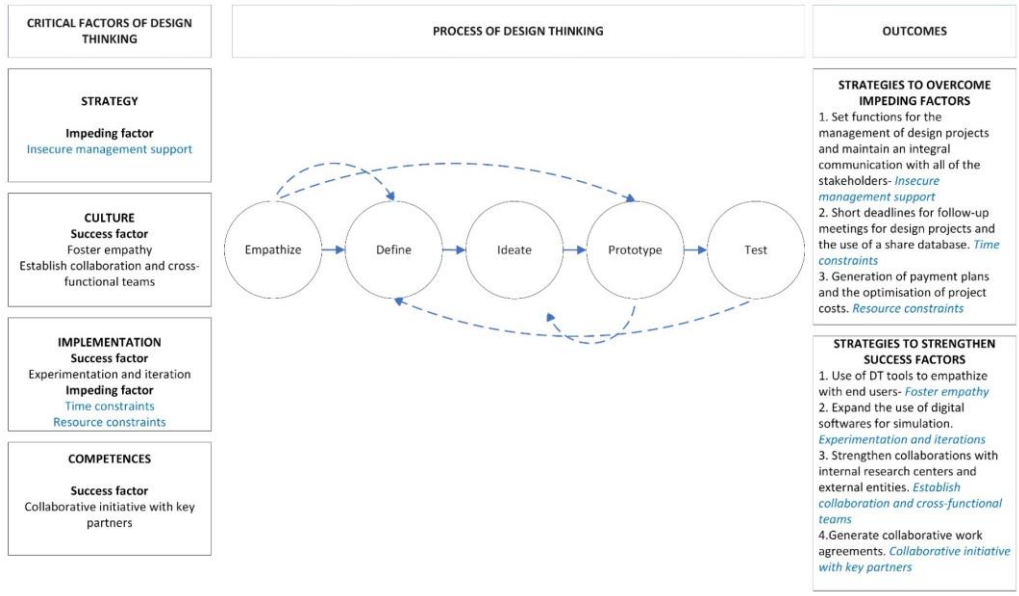

Figure 11. Design thinking framework of critical factors in university-industry collaboration spaces.
Source: Authors' own creation (2023).

5.3 Paper III

Introduction

This research underscores the importance of enhancing user involvement in traditional sectors such as agriculture, which are fundamental to sustainable development. For agricultural technologies, such as the collective greenhouse prototype, novel approaches are necessary to engage users throughout the development phase. Accordingly, this article describes and discusses the application of a journey map developed in collaboration with agricultural producers responsible for the prototype. This initiative addresses the need to safeguard agroforestry production from pests and the impacts of climate change.

This study employs a qualitative methodological approach, specifically a single case study, to examine the application of a design thinking tool—namely, the journey map—in the development of a collective greenhouse prototype. The prototyping process is facilitated by a public university with the aim of supporting two rural communities.

The questions guiding this research are the following:

RQ- What are the experiences of working with design thinking for the development of a collective greenhouse in a rural community in Bolivia?

-How can journey maps be implemented to improve user involvement when developing a collective greenhouse in the Bolivian agricultural sector?

Findings

The results demonstrate how design thinking tools, such as journey maps, enable the exploration of user experiences, uncover previously unknown needs or problems, and generate value propositions that are meaningful and relevant. Additionally, these tools help anticipate implementation issues that may not be directly related to the technology itself. Furthermore, the journey map has the potential to facilitate engagement and dialogue not only with users but also with the broader public.

Contribution to thesis

This research represents a unique exploration of the application of journey maps to enhance user involvement in the innovation process within the rural context of a lower-middle-income country such as Bolivia. The findings reveal how journey maps can serve as a design tool to actively engage agricultural producers in technology development. The implications of this research are grounded in the various types of user involvement, aiming to optimize user participation in each phase of design thinking (DT) to improve technology development. The evaluation of this tool responds to a proposed strategy for enhancing design projects within collaborative spaces in developing countries.

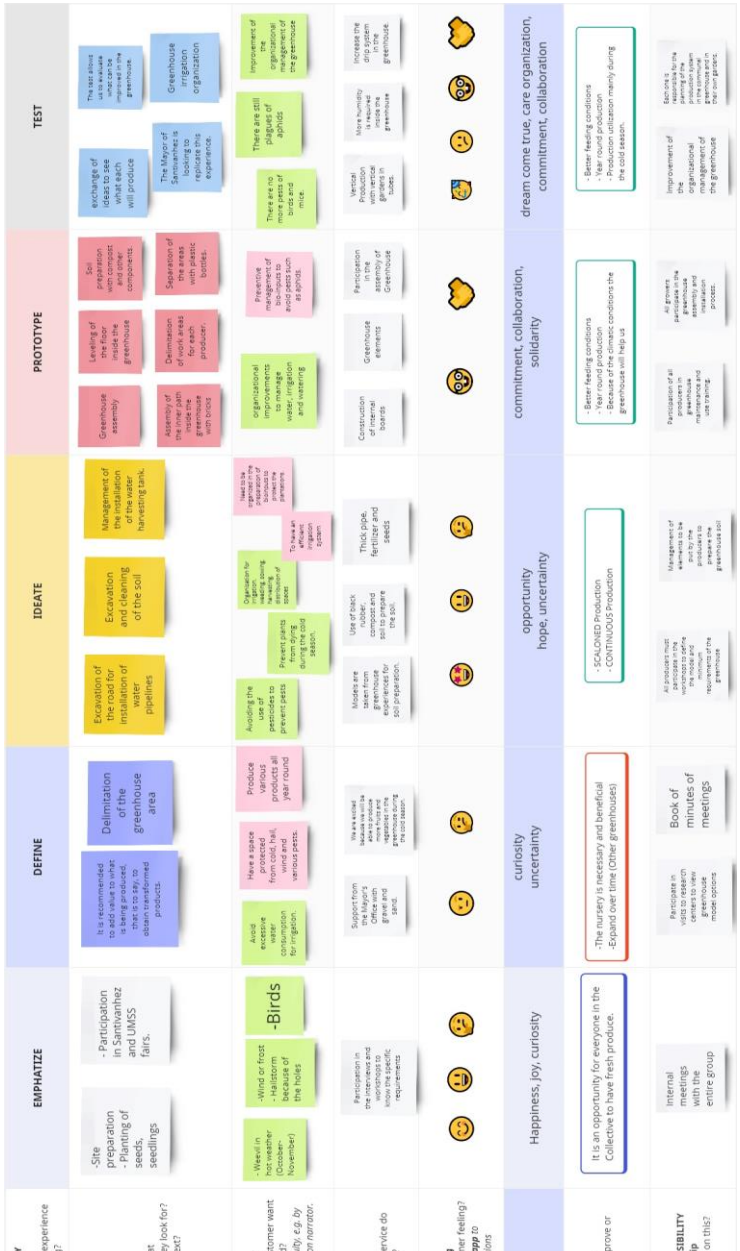

Figure 12. Application of User Journey map to Agroecological Producers (users) "Ecohuertos" of Santivañez. Source: Author's own creation (2024).

6. Discussions, conclusions, and future research

This chapter discusses the general findings presented in the licentiate thesis. Also presents the overview of findings and practical contributions, discussions of findings, thesis conclusions, contribution to the theory of literature of design thinking for prototyping and product design and development. Finally, the chapter shows the limitations of this study and future research avenues.

6.1 Overview of findings and practical contributions

The present research shows applied knowledge about design thinking to drive innovation through prototyping and product development within SMEs clusters facilitated by a public university in Bolivia. The main findings illustrated in figure 13 show a visual framework with central characteristics and critical success factors to facilitate the application of design thinking for product development in SMEs contexts. First, the visualization facilitates the SME managers' understanding of how it works and how it can be applied successfully. Second, the framework shows the most pressing and important critical success factors and strategies for SMEs with limited resources that facilitate the implementation of design thinking in SMEs clusters for development of industrial production machinery. Third, the testing of one design thinking tool such as journey map for development of local technology for rural communities contributes to explore user experiences, to gather feedback, and to enable collaborators to rethink the problem space to develop a more appropriate technology at local conditions. By testing and developing this key design tools SMEs may improve their prototyping and product development.

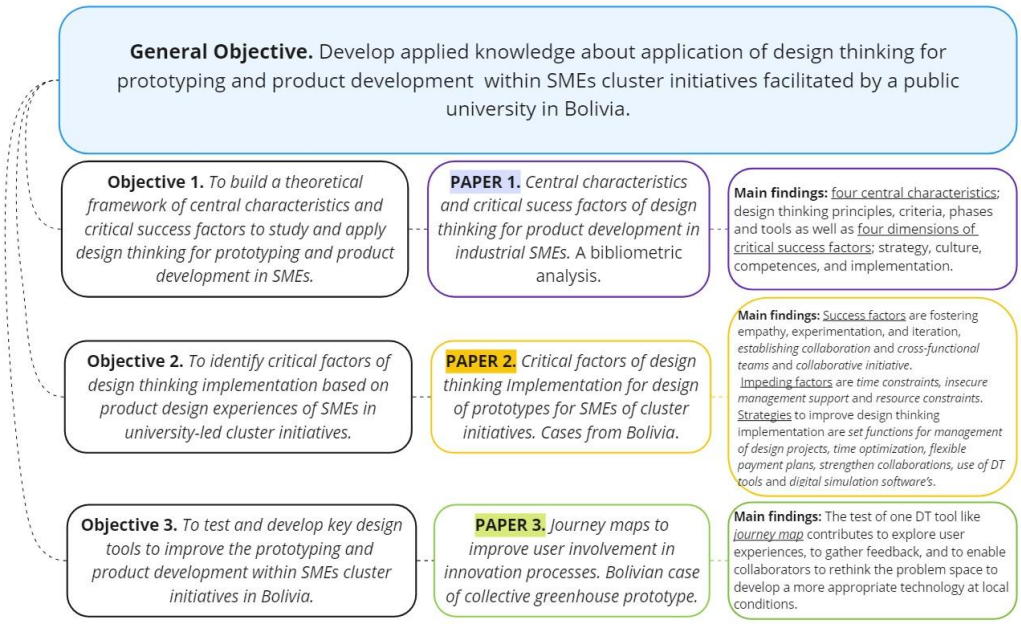

Figure 13. Overview of research and main results

This theoretical research helps to give a foundation to apply this holistic approach of design thinking in context of socio-economic sector with limited resources. As a result of these circumstances the necessity of networking with other actors, such as the university, could support in the development and innovation of new products.

Universities, as a key actor of knowledge production, play a crucial role in the development and innovation of products within resource-constrained contexts by serving as facilitators of research projects. These projects may contribute to an economic and technological country's development which attends and fulfils local needs.

The distinctiveness of this context lies in the emphasis on university-industry collaboration within resource-constrained environments, often referred to as cluster initiatives. Consequently, the effective support provided by university entities, such as technology transfer units, to the socio-productive sector—including SMEs and producers—in the development of new products may be influenced by various aspects of design thinking.

The practical contribution of design thinking to the development of prototypes and products within SMEs participating in cluster initiatives is evident through the identification of critical success factors derived from prototype design experiences. These factors are evaluated with particular attention to their capacity to mitigate the challenges typically encountered in resource-constrained environments.

Firstly, a critical success factor identified by SME managers is the importance of *securing management support* to ensure the availability of necessary resources for engaging in design thinking activities (Carlgren et al., 2016).

Secondly, success factors such as *fostering empathy* and *establishing collaboration within cross-functional teams* significantly enhance the prototype development process. By adopting the user's perspective, designers leverage empathy to more effectively identify and address the often tacit and human-centric needs of users-clients (Nakata, 2020).

Thirdly, *collaboration* and *team diversity* emerged as critical factors that facilitated the effective use of design thinking tools, thereby enhancing prototype development within SME cluster initiatives (Elsbach & Stigliani, 2018). Fourthly, *experimentation and iteration* were identified as the most crucial success factors. Experimentation allows stakeholders to explore multiple solutions, thereby maximizing the creative value of both the process and its outcomes (Gheerawo, 2018). Iterations enable designers to refine and select the optimal solution for the prototype's concept and design without incurring significant sunk costs, such as time and money (Deininger et al., 2017). This may provide relief for SMEs operating within resource-constrained environments.

Finally, *time constraints* and *resource constraints* are the critical factors recognized by the SMEs managers. This due to the lack of efficiency processing of information of design projects and the difficulty for SMEs to access financing (Flores, 2018). This caused by high costs of financing, bank requirements and insufficient company guarantees (Silvestre, 2015).

To address these challenges, SMEs should apply design thinking tools to enhance their prototype development strategies. The third study examines the application and contribution of a tool such as journey maps in the development of a collective greenhouse prototype. The use of journey maps facilitated greater empathy with users, serving as an effective means of communication (Carlgren et al., 2016; Dell'era et al., 2020). This tool proved particularly valuable in engaging with users who have low levels of education and reside in rural communities within municipalities experiencing variable climatic conditions.

6.2 Discussions of findings

The innovation for design, prototyping and development of a product can take place at every level of the society. Less favoured sectors like SMEs and farmer producers face challenges to improve its competitive position because of limited resources to invest in research and development of products. The reality of Latin American SMEs contexts shows limitations with lack of access to training, lack of financing,

lack of credibility (Encinas & Arteaga, 2007) and lack of access to technology to generate added value to production (Espejo, 2016).

Besides SMEs constrained contexts, Chou & Austin-Breneman (2017) explain that firms that effectively design their manufacturing environment within these constraints can enable more successful product development and lead to more economically sustainable development. This study addresses the prototype development process in SMEs in constrained context with similar reality of Latin American SMEs contexts, such as: limited access to input variation, restricted access to appropriate manufacturing capabilities and limitations of modelling predictions.

A key factor in the growth of SMEs is the impulse that universities may give to the entrepreneurial spirit (Encinas & Arteaga, 2007). Universities may play a supporting role to do research and to democratize knowledge, as the mission of developmental universities, which allows SMEs and farmer producers to develop their businesses and innovation capabilities. Srinivas & Sutz (2008) argue the necessity for democratizing knowledge for two reasons: first to provide effective solutions developed under conditions of scarcity to solve local problems of society, and second the importance of strengthening local SMEs and not continuing importing from more technically advanced environments. In this study the adoption of design thinking approaches and methods has been introduced as a new tool in the supporting activities between university-industry, as a way to strengthen the SMEs' and rural communities' capabilities to design, prototype and develop new industrial production machines and new agricultural production methods.

Design thinking addresses complex problems in uncertain contexts and mobilizes tools and attitudes to that end (Ben Mahmoud-Jouini et al., 2016). Nevertheless, the core of design thinking remains the ability to conceive, plan, and present ideas about products (Gloppen, 2009). The initial theoretical framework generated in paper 1 in a systematic analysis of extant research led to the creation of a visual framework outlining the central characteristics and critical success factors to enable effective application of design thinking for prototyping and product development in SMEs. The study identified four central characteristics; design thinking principles, criteria, phases and tools as well as four dimensions of critical success factors; strategy, culture, competences, and implementation. This research-based framework may facilitate the SME managers' understanding of how it works and how it can be applied successfully, which is particularly valuable for resource-constrained SMEs.

The framework provides a novel and comprehensive overview of the components and critical success factors essential for the effective application of design thinking. Certain elements are particularly significant or challenging within the context of SMEs, as evidenced by their frequent mention in the research (in study 2). Notably, the most frequently cited characteristics and critical success factors pertain to the integration of users in various capacities (e.g., user access, fostering empathy,

testing, journey maps, personas, human-centered design) and collaboration with others (e.g., initiating collaboration with key partners, establishing a culture of collaboration, co-creation with users, feasibility). These two dimensions—user integration and collaboration—are likely to be especially challenging for SMEs and rural communities due to their resource constraints. The literature extensively documents the benefits of user access in various forms, which facilitates a deeper understanding. This understanding enables technically oriented individuals and teams, as well as individuals in rural communities, to derive novel insights and develop more user-oriented product ideas by incorporating this perspective.

The utilization of visualization tools, such as customer journey maps (in study 3), storyboards, and personas, is crucial for fostering a deeper understanding of stakeholder needs and intentions. Tangible representations of ideas, including sketches, diagrams, and scenarios, inspire and facilitate communication with users, key partners, and internal stakeholders within SMEs, as well as with external actors such as consultants and universities. The use of post-it notes within this visual framework allows for adaptation to specific SMEs' and rural communities' contexts and situations, enabling re-arrangement in terms of relevance and importance during development workshops. The methodology of 'Participatory Action Research' (Kindon et al., 2007; McIntyre, 2008) employed for the development of prototypes in cluster initiatives promotes the integration of theoretical and practical approaches for knowledge construction, thereby facilitating the application of these strategies.

The initial insights from these studies show how a holistic strategy facilitated by a university like design thinking for prototyping and product development can help to solve problems in contexts like SMEs and farmers of lower middle-income countries like Bolivia. Likewise, the role developmental university plays in Latin-American countries is crucial to contribute to the local development of technology through the generation and democratization of knowledge (Arocena et al., 2015, 2017). While most of the critical success factors and impeding factors are similar to research shown in design thinking implementation in more developed countries (e.g., De Paula et al., 2019), the resource constraints for SMEs in lower-middle income countries are even more pronounced and constraining than in developed countries. Thus, the need to support SMEs and rural communities in lower-middle income countries such as Bolivia is even more important. Ultimately, the university can provide more effective support with an awareness of the specific critical success factors and overcoming the impeding factors identified in the studies.

6.3 Conclusions

The use of design thinking approaches can improve the performance of firms (Suci et al., 2022) and rural communities in the development of products, such as industrial machinery and agricultural methods, in contexts of limited resources. The utilization of design thinking has demonstrated some beneficial outcomes, but also implementation barriers in the development of prototypes tailored for SMEs and rural community producers. The beneficial outcomes are due to the user-focus, creative problem-solving, experimentation, and iteration (Björklund et al., 2020) to continuously improve the development of a product, service, process, with high utility that meet the needs of users (Chen et al., 2018). In this way, design thinking search for "integrative environments" that encourage practitioners as well as researchers to redefine problems in the search for integral solutions. The use of design thinking tools improves the communication conduits, adaptation of technical and functional aspects of prototypes and integration of endogenous knowledge of diverse stakeholders (Hehn & Uebernickel, 2018; Paay et al., 2021).

At the same time, the identification of critical and impeding factors of design thinking implementation and strategies in the SMEs clusters context are crucial to improve the processes and design of prototypes. Regarding the success factors identified are *fostering empathy* and *establishing collaborative and cross-functional teams*, in the culture dimension of design thinking. Third success factor identified is *experimentation and iterations* as part of the implementation dimension and the fourth success factor recognised is *collaborative initiative with key partners* as part of the competence dimension.

Thus, this licentiate thesis concludes that development of the strategy 'the use of design thinking tools to empathize with end users and establishing collaborative and cross-functional teams' is the most important strategy to follow in the support for developing the Bolivian SMEs' innovation capabilities. The aim of this strategy is to strengthen the successful factors of *fostering empathy* and *establishing collaborative and cross-functional teams*. In that sense, it recognizes the potential of the journey map tool for exploring user experiences, gathering feedback, and even enabling collaborators to rethink the problem space.

In this way journey maps seek to create more empathy with users in promoting creativity as a means of enterprise communication (Carlgren et al., 2016; Dell'era et al., 2020). In addition, this tool encourages the creation of value of endogenous knowledge transmitted by users as producers in the case of the rural community.

Concerning the impeding factors, three were identified: *insecure management support* within the strategy dimension, *time limitations* and *resource limitations* in the design thinking implementation dimension. These three factors are more pronounced in societies with limited resources like SMEs enterprises of a country

with lower-middle-income economies like Bolivia. In conclusion, the strategies identified to improve these impeding design thinking factors are set functions for the management of design projects to maintain an integral communication, short deadlines for follow-up meetings for design projects, flexible payment plans and the optimization of project costs to make the project accessible to SMEs.

Design thinking projects facilitated by universities and clustering of SMEs creating interactive learning spaces may contribute to the economic development of SMEs and the resource-limited countries as a whole. This is achievable through the core mission of developmental universities (Arocena et al., 2015, 2017), which is the democratization of knowledge, inherently integrated in design thinking projects. This guiding principle could inspire other universities in resource-limited countries to collaborate more effectively with SMEs and the social sector, thereby fostering local technological and socio-economic advancement.

6.4 Contributions to the literature

The knowledge gap regarding the particularities for the application of design thinking for prototyping, product and technology development in SMEs operating in contexts of resource constraints, motivates the research presented in this thesis. This study provides a theoretical framework of current research to better understand the pre-requisites of applying design thinking for prototyping and product development in SMEs.

The initial framework presented in visual form, identifies central characteristics; design thinking principles, criteria, phases and tools as well as four dimensions of critical success factors; strategy, culture, competences, and implementation. The research-based framework has been presented in visual form to facilitate use in workshops with SME managers and other stakeholders when intending to apply design thinking or struggling with its application.

Although other visual frameworks exist in the research literature on design thinking such as Rösch et al. (2023) who provide a holistic overview of the context factors, process stages, principles, tools, and outcomes, and Eisenbart et al. (2022) who present a framework outlining best practices for specific success factors, central characteristics, tools and methods, but also limitations and prerequisites for effective application of design thinking in technology-focused organizations, there is no framework specifically focused on the application of design thinking for product development in SMEs. This framework is new as it focusses on SMEs, is research-based and integrates multiple aspects of design thinking application.

Some studies like De Paula et al. (2019) provide insight into the underlying factors for an effective implementation of design thinking. This study synthesizes some

issues on how to facilitate a design thinking implementation (Liedtka, 2015) and how design thinking contributes to organizations (Carlgren et al., 2014). That is, beyond creating desirable products for customers, design thinking can improve internal organizational processes and workflows (Cankurtaran & Beverland, 2020; Kolko, 2015) inside of organizations. The underlying factors are relevant to SMEs for successfully implementing design thinking strategies and actionable steps to establish those characteristics.

SMEs with limited resources search for strategies that allows them to product development in less time and less use of resources. By this manner, the following factors like *establish collaboration and cross-functional team* arises to distribute tasks according to their capabilities. While some studies Paay et al. (2021) show that university-industry collaboration brings mutually beneficial and complementary knowledge and resources to the design and manufacture of innovative products. The role of developmental university stands up, as the actor in charge of generation and democratization of knowledge. By this way, university give support to SMEs in design projects, in which factors like *empathy, experimentation and iteration* allows to develop prototypes of products with cheaper resources.

Regarding the characteristic of design thinking tools, Elsbach & Stigliani (2018) and Liedtka (2011) identified user-focused journey mapping, visualization, ideation, cocreation, and rapid prototyping as tools for product development. In the case of customer/user journey maps the visualization of their journey allows to empathize with them and promotes a user-centered problem-solving process.

The study's conceptual framework formed the contextual basis for exploring the needed skills, processes, and structures to successfully drive design thinking within SMEs as an innovation strategy to support product development.

6.5 Limitations and future research

The limitations of this thesis lie in the following aspects:

First, there are few case studies of design projects carried out for SMEs and rural communities in clustering spaces provided by a university.

Second, there is a need for a more in-deep exploration of the actual impact of prototyping projects on SMEs, including the degree of satisfaction with the outcomes and the perceived value of these projects. While this research primarily focuses on identifying the success and impeding factors, and strategies for implementing design thinking in the context of SME clusters through prototyping projects. So, it is a missing point of view of project impact in different aspects for SMEs.

Third, the application of additional design thinking tools that could contribute to the development of satisfactory prototypes in similar university-industry collaboration contexts, such as empathy maps, personas, jobs to be done, user stories, storyboards, co-creation, virtual reality, and rapid prototyping, warrants further exploration.

Fourth, the *university perspective* was not considered in this research. Consequently, it is necessary to go deeper into issues such as the resources the university can provide and the management of the projects. The focus of this research was specifically narrowed to product-technology development for SMEs, with the *firm's perspective* serving as the foundation for the fieldwork conducted within the context of university-industry collaboration spaces.

Fifth, this thesis does not have a macro-level scope and instead focuses on specific case studies involving the application of design thinking. So, studies related to digitalization, arts and humanities, tourism, and education are not covered in this research.

Future research could explore several avenues:

- Conducting studies on additional prototyping projects for SMEs facilitated by other universities.
- Investigating the various impacts of these projects and associated support activities on SMEs.
- Examining the application of other design thinking tools for product development in SMEs within cluster initiatives or similar collaborative environments.
- Analysing how Bolivian universities can evolve into developmental universities, including the competencies and resources they can offer to SMEs. In this context, the perspective of the academic sector involved in cluster-facilitated projects could provide valuable insights and open up numerous opportunities for further research.
- Finally, extending the scope beyond the firm-level perspective to include macro-level considerations, such as public policies for promoting local technology development in resource-limited countries, could offer a broader understanding of the issues at hand.

References

Acevedo, C. (2018). Developing Inclusive Innovation Processes and Co-Evolutionary University-Society Approaches in Bolivia.

Acevedo, C., Cespedes, W. M. H., & Zambrana, J. E. (2015). "Developmental University" approaches in developing countries: Case of the Universidad Mayor de San Simon, Bolivia. In Developing Inclusive Innovation Processes and Co-evolutionary approaches in Bolivia (pp. 53–72). Blekinge Institute of Technology.

Acklin, C. (2010). Design-Driven Innovation Process Model. Design Management Journal, 5(1), 50–60. https://doi.org/10.1111/j.1948-7177.2010.00013.x

Aguirre-Bastos, C. (2017). Universities and Inclusive Development in Bolivia (pp. 97–123). https://doi.org/10.1007/978-3-319-43700-2_5

Aguirre-Bastos, C., Aliaga, J., Garrón, I., & Rubín, R. (2016). National innovation system in Bolivia and its relevance for development. . In In B. Göransson, C. Brundenius, & C. Aguirre-Bastos (Eds.), Innovation Systems for Development: Making Research and Innovation in Developing Countries Matter (pp. 84–137). Edward Elgar Publishing Limited.

Alcon Vila, A. (2022). Small and Medium Enterprises in Bolivia, a Look Back to the Future, 1900 - 2020. Journal of Evolutionary Studies in Business, 7(1), 87–120. https://doi.org/10.1344/jesb2022.1.j100

Álvarez, I., Natera, J. M., & Castillo, Y. (n.d.). Generación y transferencia de ciencia, tecnología e innovación como claves de desarrollo sostenible y cooperación internacional en América Latina.

Andreassen, T. W., Lervik-Olsen, L., & Calabretta, G. (2015). Deriving Valuable Innovations: A Trend Spotting Approach FORTHCOMING AT MANAGING SERVICE QUALITY.

Antoljak, V., & Kosović, M. (2018). Design thinking za nedizajnere – kako riješiti poslovne probleme i uspješno inovirati. Zagreb: Školska Knjiga. (in Croatian).

Aporta. (2023). Innovación social: Importancia del design thinking en la sociedad. Https://Www.Aporta.Org.Pe/Impacto/Columna/Innovacion-Social-y-Design-Thinking.

Arandia, J. P., Arevalo, J., & Acevedo, C. (2020). Estudio de los procesos de facilitación para el Desarrollo de Prototipos de Máquinas con MyPEs del Cluster de Alimentos Cochabamba. 1–132.

Arandia, J. P., & Olivares, J. (2020). Criterios de Buenas Practicas de Facilitacion para procesos de prototipaje en paises en desarrollo: Caso Cluster de Alimentos Cochabamba. DDigital - UMSS.

Arocena, R., Göransson, B., & Sutz, J. (2015). Knowledge policies and universities in developing countries: Inclusive development and the "developmental university." Technology in Society, 41, 10–20. https://doi.org/10.1016/j.techsoc.2014.10.004

Arocena, R., Göransson, B., & Sutz, J. (2017). Developmental universities in inclusive innovation systems: Alternatives for knowledge democratization in the Global South. In Developmental Universities in Inclusive Innovation Systems: Alternatives for Knowledge Democratization in the Global South. https://doi.org/10.1007/978-3-319-64152-2

Arocena, R., Göransson, B., & Sutz, J. (2018). Developmental Universities in Inclusive Innovation Systems. Springer International Publishing. https://doi.org/10.1007/978-3-319-64152-2

Arocena, R., & Sutz, J. (2012). Research and innovation policies for social inclusion: an opportunity for developing countries. Innovation and Development, 2(1), 147–158. https://doi.org/10.1080/2157930x.2012.663583

Arocena, R., & Sutz, J. (2023). La perspectiva democratizadora en el análisis de los procesos sociales de investigación e innovación. In LALICS Metodos cualitativos--para el analisis de los procesos de ciencia tecnologia e innovacion (Vol. 1, pp. 1–288).

Assink, M. (2006). Inhibitors of disruptive innovation capability: a conceptual model. European Journal of Innovation Management, 9(2), 215–233. https://doi.org/10.1108/14601060610663587

Ayala Martínez, C., & Müller, U. (2017). Towards Horizontal Cooperation and Multi-Partner Collaboration: Knowledge Sharing and Development Cooperation in Latin America and the Caribbean. https://doi.org/10.5771/9783845289427

Baldassarre, B., Calabretta, G., Karpen, I. O., Bocken, N., & Hultink, E. J. (2024). Responsible Design Thinking for Sustainable Development: Critical Literature Review, New Conceptual Framework, and Research Agenda. In Journal of Business Ethics. Springer Science and Business Media B.V. https://doi.org/10.1007/s10551-023-05600-z

Ben Mahmoud-Jouini, S., Midler, C., & Silberzahn, P. (2016). Contributions of Design Thinking to Project Management in an Innovation Context. Project Management Journal, 47(2), 144–156. https://doi.org/10.1002/PMJ.21577

Bender, R., Steier, F., Zhang, J. S., & Poldner, K. (2020). Design thinking as an effective method for driving innovative solutions to wicked problems.

Best, K. (2006). Design Management: Managing Design Strategy. Process and Implementation, AVA Publishing.

Björklund, T., Maula, H., Soule, S. A., & Maula, J. (2020). Integrating Design into Organizations: The Coevolution of Design Capabilities. California Management Review, 62(2), 100–124. https://doi.org/10.1177/0008125619898245

Bonakdar, A., & Gassmann, O. (2016). Design Thinking for Revolutionizing Your Business Models. Design Thinking for Innovation: Research and Practice, 57–66. https://doi.org/10.1007/978-3-319-26100-3_4

Bonilla, E., & Rodríguez, P. (2012). Más allá del dilema de los métodos. Bogotá: Universidad de los Andes-Norma.

Brenner, W., Uebernickel, F., & Abrell, T. (2016). Design Thinking as Mindset, Process, and Toolbox. Design Thinking for Innovation: Research and Practice, 3–21. https://doi.org/10.1007/978-3-319-26100-3_1

Brinkmann, S., & Kvale, S. (2015). Interviews: Learning the craft of qualitative research interviewing. Sage Thousand Oaks, CA.

Brown, T. (2008). Design Thinking. In Harvard Business Review. 86(6), 84–92.

Brundenius, C. , Lundvall, B.-Å. , & Sutz, J. (2009). The role of universities in Innovation systems in developing countries: Developmental university systems – Empirical, analytical and normative perspectives. In In B. Lundvall, K. J. Joseph, C. Chaminade, & J. Vang (Eds.), Handbook of Innovation Systems and Developing Countries: building domestic capabilities in a global setting (pp. 311–333). Cheltenham, UK and Northampton, MA, USA: Edward Elgar Publishing Limited. https://doi.org/10.4337/9781849803427.00019

BTI. (2024, June). Bolivia country report 2024. Https://Bti-Project.Org/En/Reports/Country-Report/BOL.

Camburn, B. A., Dunlap, B. U., Linsey, J. S., Crawford, R. H., & Wood, K. L. (2013). Methods for Prototyping strategies in Conceptual Phases of Design. 1–10. https://doi.org/https://doi.org/10.1115/DETC2013-13072

Campbell, R. I., De Beer, D. J., Barnard, L. J., Booysen, G. J., Truscott, M., Cain, R., Burton, M. J., Gyi, D. E., & Hague, R. (2007). Design evolution through customer interaction with functional prototypes. Journal of Engineering Design, 18(6), 617–635. https://doi.org/10.1080/09544820601178507

Cankurtaran, P., & Beverland, M. B. (2020). Using design thinking to respond to crises: B2B lessons from the 2020 COVID-19 pandemic. Industrial Marketing Management, 88, 255–260. https://doi.org/10.1016/j.indmarman.2020.05.030

Carlgren, L., Elmquist, M., & Rauth, I. (2014). Design Thinking: Exploring Values and Effects from an Innovation Capability Perspective. The Design Journal, 17(3), 403–423. https://doi.org/10.2752/175630614X13982745783000

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing Design Thinking: The Concept in Idea and Enactment. Creativity and Innovation Management, 25(1), 38–57. https://doi.org/10.1111/caim.12153

Chen, S., Benedicktus, R., Kim, Y., & Shih, E. (2018). Teaching Design Thinking in Marketing: Linking Product Design and Marketing Strategy in a Product Development Class. Journal of Marketing Education, 40(3), 176–187. https://doi.org/10.1177/0273475317753678

Chou, & Austin-Breneman, J. (2017). Prototyping methods for a small-to-medium manufacturing enterprise in a resource-constrained setting: A case study. In International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (Vol. 58219, p. V007T06A036). American Society of Mechanical Engineers.

Chou, & Austin-Breneman, J. (2018). Prototyping methods and constraints for small-to-medium sized enterprises in East Africa. . Development Engineering, 3, 117–124.

Clusterpedia. (2011). PACF-SICD-Clusterpedia. Clusterpedia on Cluster Development, 1(13), 1–13. www.sicd.se

Cousins, B. (2018). Design thinking: Organizational learning in VUCA environments. . Academy of Strategic Management Journal, 17(2), 1–18.

Creswell, J. W. , & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. .

Cross, N. (2011). Design Thinking: Understanding How Designers Think and Work. Berg Publishers. . https://doi.org/10.5040/9781474293884

De Jong, J. P. J., & Marsili, O. (2006). The fruit flies of innovations: A taxonomy of innovative small firms. Research Policy, 35(2), 213–229. https://doi.org/10.1016/j.respol.2005.09.007

de Paula, D., Dobrigkeit, F., & Cormican, K. (2019). Doing it right - Critical success factors for design thinking implementation. Proceedings of the International Conference on Engineering Design, ICED, 2019-August, 3851–3860. https://doi.org/10.1017/dsi.2019.392

Deininger, M., Daly, S. R., Sienko, K. H., Lee, J. C., & Street, H. (2017). Novice designers' use of prototypes in engineering design. Design Studies, 51, 25–65. https://doi.org/10.1016/j.destud.2017.04.002

Dell'era, C., Magistretti, S., Cautela, C., Verganti, | Roberto, & Zurlo, F. (2020). Four kinds of design thinking: From ideating to making, engaging, and criticizing. https://doi.org/10.1111/caim.12353

Design Council. (2022, December 7). Framework for Innovation: Design Council's Evolved Double Diamond. Available Online: Https://Www.Designcouncil. Org.Uk/Our-work/Skills-learning/Tools-frameworks/Framework-for-innovation-design-councils-evolved-double-diamond.

Donaldson, K. M. (2006). Product design in less industrialized economies: Constraints and opportunities in Kenya. Research in Engineering Design, 17(3), 135–155. https://doi.org/10.1007/s00163-006-0017-3

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Dorst, K. (2011). The core of "design thinking" and its application. Design Studies, 32(6), 521–532. https://doi.org/10.1016/j.destud.2011.07.006

Drezner, J. A. (1992). The Nature and Role of Prototyping in Weapon System Development. https://www.rand.org/pubs/reports/R4161.html%0Ahttp://www.rand.org/pubs/reports/R4161.html. Also available in print form.

Edquist, C., & Hommen, L. (1999). Systems of innovation: theory and policy for the demand side. Technology in Society, 21(1), 63–79.

Eisenbart, B., Bouwman, S., Voorendt, J., McKillagan, S., Kuys, B., & Ranscombe, C. (2022). Implementing design thinking to drive innovation in technical design. International Journal of Design Creativity and Innovation, 10(3), 141–160. https://doi.org/10.1080/21650349.2022.2048698

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. Academy of Management Review.

Elsbach, K. D., & Stigliani, I. (2018). Design Thinking and Organizational Culture: A Review and Framework for Future Research. Journal of Management, 44(6), 2274–2306. https://doi.org/10.1177/0149206317744252

Elverum, C. W., Welo, T., & Steinert, M. (2014). The Fuzzy Front End: Concept Development in the Automotive Industry. Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, August, 9. https://doi.org/10.1115/detc2014-35138

Encinas, J. D., & Arteaga, J. (2007). OBSTACULOS, LOGROS Y DESAFIOS DE LA MIPYMES EN BOLIVIA. In Las MIPYMES en Latinoamérica Estudios e Investigaciones en la Organización Latinoamericana de Administración (pp. 38–49).

Espejo, M. (2016). MONOGRAFÍA RÉGIMEN TRIBUTARIO ESPECIAL PARA MICRO , PEQUENAS Y MEDIANAS EMPRESAS (MIPYMES).

Fagerberg et al. (2005). Innovation- A guide to the literature.

Ferrara, M., Di Milano, P., & Chiara Lecce, I. (2020). "Design for Enterprises": Developing European SMEs capabilities for design-driven innovation. Markets, Globalization & Development Review, 4(2). https://doi.org/10.23860/MGDR-2019-04-02-07

Flores, J. (2018). La Bolsa Boliviana de Valores como alternativa de financiamiento para las PyMEs de la ciudad de Cochabamba The Bolivian Stock Exchange as a financing alternative for the SMEs in the city of Cochabamba. Revista Perspectivas, 71–96. https://www.bbv.com.bo/ResenaHistorica

Foster, C., & Heeks, R. (2013). Conceptualising inclusive innovation: Modifying systems of innovation frameworks to understand diffusion of new technology to low-income consumers. European Journal of Development Research, 25(3), 333–355. https://doi.org/10.1057/ejdr.2013.7

Garcia, R. (2024, June). Rocío García: "El método Design Thinking es ideal para aplicarlo en el tercer sector." Fundacion MTP.

Garcia, R., & Dacko, S. (2015). Design Thinking for Sustainability. In M. Luchs, K. Scott, & A. Griffin (Eds.), Design Thinking. New Product Development Essentials from the PDMA (Vol. 1, Issue 25, pp. 401–423). Jhon Wiley & Sons, Inc. Hoboken. https://doi.org/10.1049/oap-cired.2017.1227

Geissdoerfer, M., Bocken, N. M. P., & Hultink, E. J. (2016). Design thinking to enhance the sustainable business modelling process e A workshop based on a value mapping process. https://doi.org/10.1016/j.jclepro.2016.07.020

Gheerawo, R. (2018). Design Thinking and Design Doing: Describing a Process of People-Centred Innovation. In Advanced Sciences and Technologies for Security Applications (pp. 11–42). Springer. https://doi.org/10.1007/978-3-319-78021-4_2

Gloppen, J. (2009). Perspectives on Design Leadership and Design Thinking and How They Relate to European Service Industries. Design Management Journal - Des Manag J, 4, 33–47. https://doi.org/10.1111/j.1942-5074.2009.00005.x

Greenwood, D. J., & Levin, M. (1998). Action research, science, and the co-optation of social research. . Studies in Cultures, Organizations and Societies, 4(2), 237–261.

Hassi, L., & Laakso, M. (2011). DESIGN THINKING IN THE MANAGEMENT DISCOURSE: DEFINING THE ELEMENTS OF THE CONCEPT. In 18th International Product Development Management Conference, IPDMC, 1–14.

Hehn, J., & Uebernickel, F. (2018). The use of design thinking for requirements engineering: An ongoing case study in the field of innovative software-intensive systems. Proceedings - 2018 IEEE 26th International Requirements Engineering Conference, RE 2018, 400–405. https://doi.org/10.1109/RE.2018.00-18

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. Thinking Skills and Creativity, 26, 140–153. https://doi.org/10.1016/J.TSC.2017.10.001

Ingstrup, M. B. (2010). The role of cluster facilitators. International Journal of Globalisation and Small Business, 4(1), 25–40. https://doi.org/10.1504/IJGSB.2010.035329

International Trade Administration. (2022). Bolivia - Country Commercial Guide. Https://Www.Trade.Gov/Country-Commercial-Guides/Bolivia-Equipment-and-Machinery.

Iriarte, N., & Acevedo, C. (2020). ELEMENTOS PARA EL DISEÑO DE POLITICAS DE INNOVACIÓN TECNOLÓGICA Y COLABORACIÓN UNIVERSIDAD – EMPRESA EN COCHABAMBA. 1–104.

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. Journal of Advanced Nursing, 72(12), 2954–2965.

Katz, J. (2007). CAMBIOS ESTRUCTURALES Y CICLOS DE DESTRUCCION Y CREACION DE CAPACIDADES PRODUCTIVAS Y TECNOLOGICAS EN AMERICA LATINA (Issue The global network for economics of learning, innovation and competence building system).

Kelley, T., & Kelley, D. (2013). Creative confidence: Unleashing the creative potential within us all. Currency.

Kelley, T., & Littman, J. (2006). The Ten Faces of Innovation IDEO's Strategies for Defeating the Devil's Advocate and Driving Creativity Throughout Your Organization (p. 275). Doubleday.

Kenney, M. (2001). The Temporal Dynamics of Knowledge Creation in the Information Society.

Kindon, S., Pain, R., & Kesby, M. (2007). Participatory Action Research Approaches and Methods: Connecting people, participation and place. London and New York: Routledge.

Kindon, S., Pain, R., & Kesby, M. (2015). Participatory action research. Research in the College Context: Approaches and Methods, 81–94. https://doi.org/10.4324/9781315740447-12

Klewitz, J., & Hansen, E. G. (2014). Sustainability-oriented innovation of SMEs: a systematic review. Journal of Cleaner Production, 65, 57–75. https://doi.org/10.1016/J.JCLEPRO.2013.07.017

Knight, E., Daymond, J., & Paroutis, S. (2020). Design-Led Strategy: How To Bring Design Thinking into the Art of Strategic Management. California Management Review, 62(2), 30–52. https://doi.org/10.1177/0008125619897594

Kolko, J. (2014). Well-designed: how to use empathy to create products people love. . Harvard Business Press.

Kolko, J. (2015). Design Thinking Comes of Age. . Harvard Business Review. Https://Hbr.Org/2015/09/Design-Thinking-Comes-of-Age/ .

Kwon, J., Choi, Y., & Hwang, Y. (2021). Enterprise Design Thinking: An Investigation on User-Centered Design Processes in Large Corporations. Designs 2021, Vol. 5, Page 43, 5(3), 43. https://doi.org/10.3390/DESIGNS5030043

Latifi, M. A., Nikou, S., & Bouwman, H. (2021). Business model innovation and firm performance: Exploring causal mechanisms in SMEs. Technovation, 107. https://doi.org/10.1016/j.technovation.2021.102274

Lauff, C. A., Kotys-Schwartz, D., & Rentschler, M. E. (2018). What is a prototype? what are the roles of prototypes in companies? Journal of Mechanical Design, 140(6). https://doi.org/10.1115/1.4039340

Lawson, L., & Meijers, J. (2024). ¿Cuáles son algunas estrategias para superar los recursos limitados cuando se utiliza el pensamiento de diseño para la innovación de productos? LinkedIn.

Lepratte, Thomas, H., & Yoguel, G. (2011). Sociotechnical systems, innovation and development. . Munich Personal RePEc Archive, (33559), 26. Retrieved from Https://Mpra.Ub.Uni-Muenchen.de/33559/ .

Liedtka, J. (2011). Learning to use design thinking tools for successful innovation. Strategy and Leadership, 39(5), 13–19. https://doi.org/10.1108/10878571111161480

Liedtka, J. (2015). Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. In Journal of Product Innovation Management (Vol. 32, Issue 6, pp. 925–938). https://doi.org/10.1111/jpim.12163

Liedtka, J. (2017). Evaluating the impact of design thinking in action. 2017 Annual Meeting of the Academy of Management, AOM 2017, 2017-August. https://doi.org/10.5465/AMBPP.2017.177

Liedtka J., & Ogilvie T. (2011). Designing for growth: A design thinking toolkit for managers. Columbia Business School Publishing.

Lindqvist, G., Ketels, C., & Sölvell, örjan. (2003). The Cluster Initiative Greenbook 2.0. In Annual Global Conference in Gothenburg.

Luna, E., & Rodriguez, L. (2011). Pautas para la elaboración de estudios de caso. Lecciones Aprendidas, 10. http://econpapers.repec.org/RePEc:idb:brikps:13018

Martin, B. , & Hanington, B. (2012). Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. Rockport Publishers.

Martin, R. (2009). The Design of Business: Why Design Thinking Is the next Competitive Advantage - DESIGNING A BUSINESS.

McIntyre, A. (2008). Participatory action research. Los Angeles, London, New Deli and Singapore: Sage Publications., 52.

Micheli, P., Perks, H., & Beverland, M. B. (2018). Elevating Design in the Organization. Journal of Product Innovation Management, 35(4), 629–651. https://doi.org/10.1111/JPIM.12434

Micheli, P., Wilner, S. J. S., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). Doing Design Thinking: Conceptual Review, Synthesis, and Research Agenda. Journal of Product Innovation Management, 36(2), 124–148. https://doi.org/10.1111/jpim.12466

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). Qualitative Data Analysis_ A Methods Sourcebook. SAGE Publications.

Miles, M. B., Huberman, A. M., & Saldana, J. (2020). Qualitative Data Analysis: A Methods Sourcebook (SAGE Publication). https://books.google.com.bo/books?hl=es&lr=&id=lCh_DwAAQBAJ&oi=fnd&pg=PP1&dq=miles+m+b+huberman&ots=2SgqMByi9g&sig=mt8D8ixXyxYNeIpgHjrBoUNuMhc&redir_esc=y#v=onepage&q&f=true

Moe, R. E., Jensen, D. D., & Wood, K. L. (2004). DETC2004-57221 PROTOTYPE PARTITIONING BASED ON REQUIREMENT FLEXIBILITY. 1–13.

Naiman, L. (2019, May 20). Design Thinking as a Strategy for Innovation. The European Business Review. https://www.europeanbusinessreview.com/design-thinking-as-a-strategy-for-innovation/

Nakata, C. (2020). Design thinking for innovation: Considering distinctions, fit, and use in firms. Business Horizons, 63(6), 763–772. https://doi.org/10.1016/j.bushor.2020.07.008

OECD/Eurostat. (2018). The Measurement of Scientific, Technological and Innovation Activities. In OECD (Ed.), Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation (4th Edition). OECD Publishing. https://doi.org/10.1787/9789264304604-en

Olivares, J. (2020). Aprendizajes en Ingeniería y Gestión de prototipado en centros de investigación de metalmecánica de la universidad Mayor de San Simón. Universidad Mayor de San Simón.

Olivares, J., & Arévalo, J. (2022). Aprendizajes en ingeniería de prototipado en centros de investigación de una universidad pública en Bolivia. I+Diseño. Revista Científico-Académica Internacional de Innovación, Investigación y Desarrollo En Diseño, 17, 77–102. https://doi.org/10.24310/idiseno.2022.v17i.15221

Paay, J., Kuys, B., & Taffe, S. (2021). Innovating product design through university-industry collaboration: Codesigning a bushfire rated skylight. Design Studies, 76. https://doi.org/10.1016/j.destud.2021.101031

Pap, M., Vdović, R., & Baletić, B. (2019). Design Thinking metoda u znanstvenom istraživanju, edukaciji i poslovnoj praksi. Prostor, 27(2 (58)), 334–347. https://doi.org/10.31522/P.27.2(58).12

Rösch, N., Tiberius, V., & Kraus, S. (2023). Design thinking for innovation: context factors, process, and outcomes. European Journal of Innovation Management, 26(7), 160–176. https://doi.org/10.1108/EJIM-03-2022-0164

Rydhagen, B. (2002). Feminist Sanitary Engineering as a Participatory Alternative in South Africa and Sweden. http://www.bth.se

Säfsten, K., & Gustavsson, M. (2020). Research methodology: for engineers and other problem-solvers.

Sampieri, R. (2014). Metodologia de la investigacion (Sexta edic). McGRAW-HILL / INTERAMERICANA EDITORES, S.A. DE C.V. Edificio.

Sandoval, C. A. (2002). La Investigación Cualitativa. Bogotá, ICFES-ASCUN. Icfes.

Schlecht, L., & Yang, M. (2014). Impact of Prototyping Resource Environments and Timing of Awareness of Constraints on Idea Generation in Product Design. Technovation, 34, 223–231. https://doi.org/10.1016/j.technovation.2013.11.001

Sense, A. J. (2006). Driving the Bus from the Rear Passenger Seat: Control Dilemmas of Participa tive Action Research. . International Journal of Social Research Methodology, 9(1), 1–13.

Siang, Y. T. (2020). Design thinking. Interaction Design Foundation.

Silvestre, E. (2015). El problema del Financiamiento de las PYMES en Bolivia.

Srinivas, S., & Sutz, J. (2006). Economic development and innovation: problem-solving in scarcity conditions. CID Graduate Student and Postdoctoral Fellow Working Paper Series.

Srinivas, S., & Sutz, J. (2008). Developing countries and innovation: Searching for a new analytical approach. Technology in Society, 30(2), 129–140. https://doi.org/10.1016/J.TECHSOC.2007.12.003

Stickdorn, M. , Schneider, J. , Andrews, K., & Lawrence, A. (2011). This is service design thinking: Basics, tools, cases. Hoboken, NJ: Wiley., 1.

Stuart, I., Mccutcheon, D., Handfield, R., Mclachlin, R., & Samson, D. (2002). Effective case research in operations management: a process perspective. In Journal of Operations Management (Vol. 20).

Suci, A., Maryanti, S., Hardi, H., & Sudiar, N. (2022). Embedding Design Thinking Paradigm in a University's Business Assistance to Small Business. Systemic Practice and Action Research, 35(2), 177–201. https://doi.org/10.1007/s11213-021-09565-w

The World Bank. (2023). Lower Middle Income Economies. Https://Data.Worldbank.Org/Country/XN.

Tracy, S. J. (2020). Qualitative research methods: collecting evidence, crafting analysis, communicating impact. Hoboken, NJ, Wiley-Blackwell.

Trojer, L., & Rydhagem, B. (2014). THE ROLE OF UNIVERSITIES IN INCLUSIVE INNOVATION Cluster development in East Africa. Nelson Mandela African Institute for Science and Technology, Arusha, Tanzania.

Ulrich, K. T., Eppinger, S. D., & Yang, M. C. (2020). Product Design and Development. In McGraw-Hill Education (Vol. 7, Issue 2). https://doi.org/10.1016/0956-5663(92)90013-D

VCyT. (2013). Plan Nacional de Ciencia, Technología e Innovación. La Paz, Bolivia.

Wadsworth, Y. (2006). The mirror, the magnifying glass, the compass and the map: Facilitating participatory action research. . In Handbook of action research (pp. 322–342). The concise paperback edition.

Wardale, D. (2008). A proposed model for effective facilitation. . Group Facilitation: A Research and Applications Journal, 9(1), 49–58.

Wölbling, A., Krämer, K., Buss, C. N., Dribbisch, K., LoBue, P., & Taherivand, A. (2012). Design Thinking: An Innovative Concept for Developing User-Centered Software. Management for Professionals, Part F393, 121–136. https://doi.org/10.1007/978-3-642-31371-4_7

Yin, R. K. (2018). Case Study Research and Applications. Sage Publications.

Zevallos Vallejos, E. (2007). Restricciones del entorno a la competitividad empresarial en América Latina. San José de Costa Rica, Costa Rica, FUNDES Internacional.

Paper I

businesses

MDPI

Systematic review

Central characteristics and critical success factors of design thinking for product development in industrial SMEs – A bibliometric analysis

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Abstract: Design thinking is an innovative methodology that may be applied by small and medium enterprises which emphasizes a human-centered approach to problem-solving facilitating the creation of novel solutions for complex and open-ended challenges, like the development of new products. Despite its recognized importance in business and academia, many industrial SMEs struggle with applying design thinking in their product development processes. This research aims to identify the central characteristics of design thinking and critical success factors to enable effective application by industrial SMEs. Based on a systematic search in the Scopus database (last searched May 14th 2024) for relevant literature, resulting in a selection of 30 published papers, with titles and/or abstract fields containing words of design thinking and small- and medium-sized enterprises in industrial sectors, and a bibliometric analysis of co-word occurrence, using VOS software, we construct a framework that identifies central characteristics; design thinking principles, criteria, phases and tools as well as four dimensions of critical success factors; strategy, culture, competences, and implementation. The finding is new as it applies to industrial SMEs compared to extant research's more general orientation. The framework is presented in visual form to facilitate use in developmental workshops with SMEs and supporting actors. The paper ends with notes on limitations and proposals for further research.

Keywords: Design thinking; innovation; product development; small and medium-sized enterprises; critical success factors; visual framework

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1. Introduction

The industrial panorama increasingly calls for multidisciplinary design professionals who are able to apply design thinking and engineering knowledge in developing new products and services. Design thinking improves an organisation's ability to innovate [1,2]. Innovation involves design exploration resulting in new products and services, including the creative redesign of existing products, adding value for the company and end-user. Innovation is recognised to be critical to small and medium-sized enterprises' (SMEs') survival and development [3]. In spite of their relative weak financial power and limited resources, SMEs may thrive through a commitment to innovation in services and products [4].

The fast evolution of technology has had the effect of dramatically shortening the life cycle of innovative products [5]. As a result, the need arises to adopt holistic strategies, to maintain competitiveness and offers a more sustainable future [5]. Application of design

thinking in enterprises enables them to identify key actors and the users of service [6] to conceptualize, prototype, develop solutions, and to enhance communications [7].

Extant research suggests that large-sized organizations support and utilize design thinking, but a literature gap exists on how SMEs can successfully adopt design thinking within their long-term strategic management plan [8,9]. While large organizations continue to implement design thinking, SME leaders struggle to adopt design thinking processes effectively [10,11]. This knowledge gap regarding the particularities for the application of design thinking for product and technology development in SMEs motivates the research presented in this paper which proposes to build a bibliometric-based framework of current research to better understand the pre-requisites of applying design thinking for product development in industrial SMEs.

The question guiding this research is the following: Which are the central characteristics and critical success factors that are needed to facilitate the effective application of design thinking for product development in industrial SMEs?

The aim is to construct a framework for application of design thinking in industrial SMEs that can provide guidance to industrial SME managers and other stakeholders supporting the development of SMEs, i.e., giving an overview of current research as well identifying the most salient issues in application of design thinking for product development.

2. Conceptual Background

2.1. Definition of design thinking

Design thinking is emerging in the management literature as a concept that promises innovation through a more user-centred approach which suggests that companies can learn from the way designers think and work [12,13]. As a result, it has been introduced in many different organizational settings, such as SMEs [14], to solve complex and open-ended problems, like new product development. According to [15], there is a growing interest for design thinking (DT) among managers, because the integration of the DT process into the SME's product development strategy will improve its competitive position [16]. However, the integration of DT into the product development process can be approached in various ways. To fully comprehend the potential benefits of DT for product development, it is essential to understand the different manifestations of DT. Scholars have identified three primary forms of DT application: as a mindset, as a process, and as a toolbox [17,18].

When considered as a mindset, DT is characterized by several key principles, including a strong focus on both explicit and latent customer and user needs, as well as an emphasis on prototyping [18]. Nonetheless, it has been argued that applying these principles in isolation—without a structured framework—can be overly challenging for novices [18]. Consequently, in certain scenarios, a structured process is necessary to facilitate novice comprehension of what DT is and how it can contribute to the product development process.

Additionally, various collections of design tools exist, catering to both practitioners [19] and academics [20]. The deployment of appropriate methods is a critical success factor in DT projects [18]. Therefore, it is imperative that product development teams possess a thorough understanding of how to apply these methods effectively. Thus, the generation of a research-based framework with the central characteristics and critical success factors of DT may facilitate the SME managers' understanding of how it works and how it can be applied successfully. This is especially important for SMEs, with limited financial and other resources. While larger companies usually can withstand the consequences of failed product development projects, SMEs have a much lower-level resilience against such failures. Thus, learning lessons from previous product development projects are essential to guide SMEs comprehensively in the application of design thinking into the product development process.

DT is distinct from traditional new product development methodologies due to its greater emphasis on comprehensively understanding the user. This approach employs methods such as user profiles, journey maps, and co-design to gain deeper insights into users' needs and experiences. DT aims to reframe problems by identifying the fundamental issues and underlying reasons behind user preferences and behaviors. It emphasizes generating a variety of solutions, utilizing rapid prototyping, and adopting a strategy of "failing early" to achieve success more swiftly [21].

Successful application of DT can be achieved by identifying its critical success factors (CSFs). These are defined as items or actions that should be present in a particular project or situation to be successful [22]. By identifying the CSFs, companies can proactively implement necessary measures to avoid potential failures or problematic areas, thereby enhancing the success rate of implementing DT. The research of De Paula et al., [23] contributes with the identification of 20 CSFs divided in 4 key dimensions to understand how to successfully implement design thinking in business organizations.

Table 1 shows more details about the theoretical origin of 20 CSFs grouped in four dimensions namely strategy, culture, implementation and competences.

Table 1. Criitical success factors in DT application. Source: de Paula et al. (2019).

Dimensions	Factors	Source
Strategy	Secure management support	[20,24–26] Carlgren et al. (2016), Holloway (2009), Rosensweig (2011), Hassi & Laakso (2011)
	Having fundamental guidelines for design thinking	[20,25,27] Rosensweig (2011), Kimbell (2009), Hassi & Laakso (2011)
	Ensure fundings for design thinking initiatives	[12,26] Carlgren et al. (2016), Brown (2008)
	Having clear metrics	[15,28] Carlgren, Rauth, et al. (2016), Liedtka (2011)
Culture	Diversity orientation	[20,24,25] Holloway (2009), Rosensweig (2011), Hassi & Laakso (2011)
	Foster empathy	[12,27–29] Brown (2008), Kimbell (2009), Liedtka (2011), Lockwood (2009)
	Ability to handle ambiguous situations	[30–32] Dunne et al. (2006), Gloppen (2009), Sato et al. (2010)
	Ability to handle complexity and uncertainty	[28,33–35] Liedtka (2011), Boland & Collopy (2004), Cooper et al. (2009), Dew (2007)
	Establish collaboration and cross-functional teams	[30–32] Dunne et al. (2006), Gloppen (2009), Sato et al. (2010)
Implementation	Provide necessary material	[36,37] Micheli et al. (2012), Carlgren et al. (2014)
	Innovation spaces	[12,37] Carlgren et al. (2014), Brown (2008)
	Establish flexible and responsive processes	[18,24,25]Holloway (2009), Rosensweig (2011), Brenner et al. (2016)
	Integrate DT into NPD and related processes	[25,36] Micheli et al. (2012), Rosensweig (2011)
	Apply lessons learned from past projects	[17,18,26] Wölbling et al. (2012), Carlgren, Elmquist, et al. (2016), Brenner et al. (2016)
	Access to the user	[12,24,38] Brown (2008), Holloway (2009), Ward et al. (2009)
Competences	Provide training on DT	[25,26,36] Micheli et al. (2012), Carlgren, Elmquist, et al. (2016), Rosensweig (2011)
	Collaborative initiative with key partners	[25,36] Micheli et al. (2012), Rosensweig (2011)
	Create DT awareness	[30,32,37] Dunne et al. (2006), Sato et al. (2010), Carlgren et al. (2014)

	Enable the optimal team skills	[12,26,39] Carlgren, Elmquist, et al. (2016), Brown (2008), Seidel & Fixson (2013)
	Include DT principles into everyday work	[12,26,28]Carlgren, Elmquist, et al. (2016), Brown (2008), Liedtka (2011)

3. Research Design and Methodology

This study adhere to the PRISMA 2020 guidelines in its relevant parts. This paper applies a two-stepped methodology: a systematic search of relevant literature using a search string in the database Scopus, (last search in May 14th 2024) and then a bibliometric analysis of keywords and abstracts in selected papers. In doing so, characteristics and variables involved in the process of DT application for development of new product/technology for SMEs were identified. Bibliometric analysis is an effective method of summarizing and synthesizing literature [40]. The process of systematic search was divided in four steps: 1) Define the search string, 2) filter the search outcomes according to selection criteria, 3) exclude papers that do not follow the string domain and inclusion of additional papers according to snowball sampling, 4) analyse the included literature to gain insights.

3.1. Definition of Search String

The search query was composed of the following keywords "Design thinking" * AND "Innovation" AND (sme* OR smes* OR "small and medium-sized enterprise" OR "small and medium enterprise" OR "small medium enterprise" OR "small and medium-sized firm" OR "small and medium firm" OR "small firm" OR "medium firm" *)

3.2. Filtering criteria and process

The search string included articles, conference papers and book chapters in Engineering or Business, Management and Accounting Subjects areas in English and German language.

3.3. Exclusion of papers and inclusion of additional papers

The excluded papers are studies related to digitalization, arts and humanities, tourism and education, i.e., services, not covered in this research. Hence the focus on industrial SMEs. The search query yielded 25 articles, of which 17 articles were selected because they showed factors and pre-requisites to facilitate the application of DT for the development of products. Additionally, 13 articles were collected by snowball sampling, making a total of 30 articles, which were published between 2011 and 2023. Figure 1 summarizes the research method followed for this research. The 30 articles filtered from Scopus and snowball sampling are listed in table A1 in the Appendix.

3.4. Analysis of eligibility

The consistency of information that matches with the main criteria follow the main conditions:

- The title, abstracts and keywords of the literature must include the terms ‘design thinking’ AND ‘SMEs’
- The application of the use of design thinking should be focused on developing new products or new technologies.

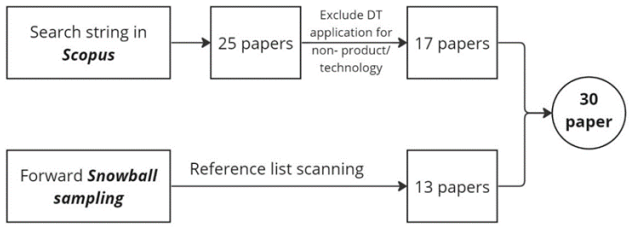

Figure 1. Selection process of papers included in the study.

The first author independently performed the searches in the database and did a first selection of inclusion and exclusion of papers. The second author checked and confirmed the selection of papers. The first author collected the data from the selected papers, the title and abstract fields, and prepared the data for analysis.

4. Results

The bibliometric analysis of keywords and abstracts aims to identify and describe relevant pre-requisites needed to facilitate the application of DT in the context of industrial SMEs.

4.1. Bibliometric analysis

The central characteristics were identified based on the visualization of group network obtained in the key word co-occurrence analysis of titles and abstract fields of the selected papers showed in Figure 2. The potential contributions of content co-occurrence analyses include syntheses of the literature based on themes and related publications that form disparate research streams that are mapped into a taxonomy [41]. The key word co-occurrence analysis of titles and abstract fields of the 30 papers filtered and uploaded in research rabbit, application of 'citation-based literature mapping tool', to obtain the database in a Research Information Systems Document (.ris). No data was missing, all papers had titles and abstract fields. This database is exported at VOS viewer software, a tool for constructing and visualizing bibliometric networks. Bibliometric analysis allows to model the evolution of concepts and identify topics studied in a field of inquiry [42,43]. A bibliometric network consists of nodes and edges. The nodes can be publications, journals, researchers and keywords and the edges indicate relation between pairs of nodes. VOS viewer used techniques for mapping and clustering the nodes in a network [44]. A cluster is a set of closely related nodes.

The networks of keyword co-occurrence analysis (co-word analysis) enables us to visualize the relationships of keywords or topics to one another [42–44]. Co-word analysis is a text-mining technique that analyzes the 'co-occurrence' of pairs of keywords in the selected documents [44]. This analysis assumes that keywords that frequently appear together (i.e., co-occur) in the same document bear a relationship to one another.

The parameters for the software are minimum number of key word co-occurrences defined as 2 as recommended by [45] Baier-Fuentes et al. (2018), with a minimum threshold of 95 items and 6 clusters. The co-word analysis indicates the key terms more frequently used in the literature (bigger nodes in Figure 2) like design thinking, innovation, SME, study, approach, process, product and tool.

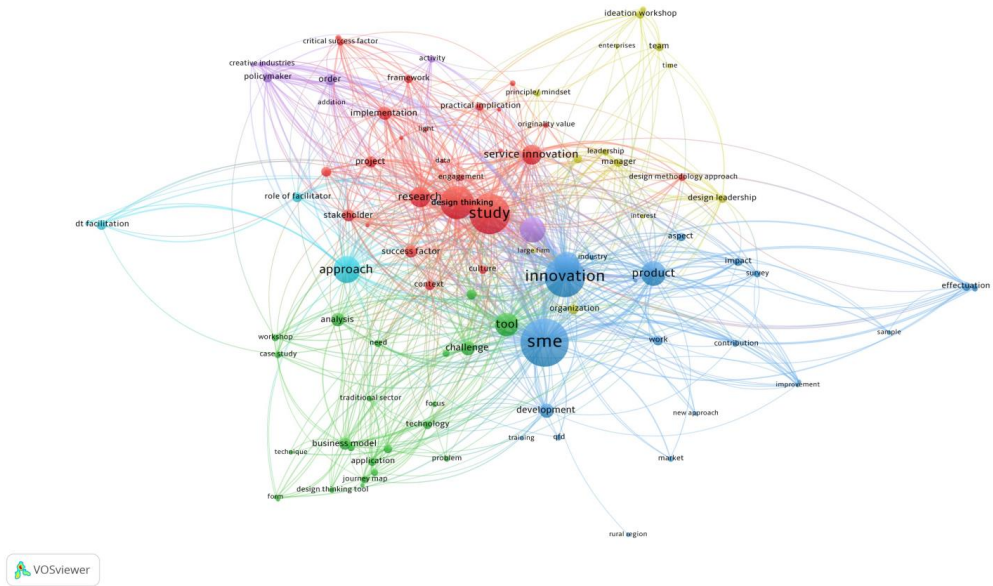

Figure 2. Visualization of DT characteristics based on co-occurrence analysis of abstracts and keywords. Source: prepared by authors based on Research Rabbit data and VOS viewer software. .

The six clusters identified in Figure 2 can be described as follows in order of highest to lowest degree of absolute frequency:

The red cluster with 25 items (26,32 % of total items) focuses on the dimensions of critical success factors like culture and implementation of design thinking. Additionally, it is recognized that some critical factors like management support inside the strategy dimension and knowledge exchange among stakeholders as part of culture dimension.

The green cluster with 23 items (24,21%) is related to the application of design thinking tools for different levels of innovation like application/adoption of technology, business models and ecosystems. Tools identified are e.g., journey map and point of view.

The blue cluster with 23 items (24,21%) relates to both design thinking tools and critical success factors, with an emphasis on SMEs, such as QFD and surveys applied for development of products for SMEs. The critical success factors identified belong to the competence dimension, like training and development.

The yellow cluster with 13 items (13,68 %) focuses on principles/mindsets, such as experimentation, team organization and design leadership to improve the product development of enterprises.

The purple cluster with 7 items (7,37%) emphasizes the process of activating new avenues of innovation like design thinking applied to inexperienced actors in design field. Design thinking can be learnt and adopted by SMEs from large firms and by policymakers to enable SMEs to co-create with creative industries [46].

Finally, the light blue cluster with 4 items (4,21%) shows the emphasis on design thinking facilitation criteria like desire, feasible, viable and sustainable/circular approach. Additionally highlights the role of facilitator and the taxonomy of design thinking approach.

In summary, the central characteristics of design thinking identified by the six clusters in the co-word analysis are: tools, levels of innovation, principles/mindsets, phases or process of design thinking, facilitation criteria and critical success factors.

4.2 Details of central characteristics for application of design thinking identified based on co-word analysis

Table A1 highlights the themes (clusters) of central characteristics for integration of DT in SMEs identified in the bibliometric analysis of keywords in the 30 papers, i.e., principles/mindsets, facilitation criteria, innovation phases, levels of innovation, tools and CSFs. The table A1 provides a novel view for DT application in SMEs based on the selected papers. Figure 3 shows the absolute frequencies for central characteristics of design thinking obtained in the analysis of the 30 papers detailed in Table A1.

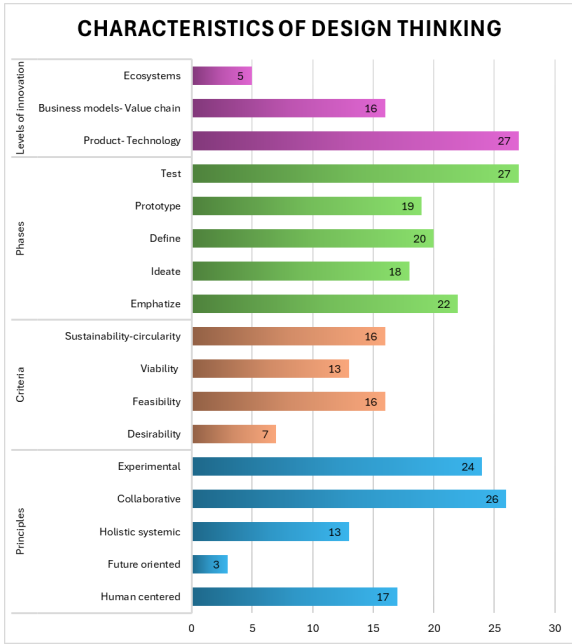

Figure 3. Absolut frequencies for central characteristics of design thinking.

The *level of innovation* relates to the product/technology, business model, or ecosystem levels [67,68]. The analysis on *level of innovation* shows in purple bar of Figure 3 that at least 90 % of all selected papers used design thinking for developing a product or some technology. While designers have traditionally focused on technology and product design, the intersection of products, services, and business models is emerging as a significant area of emphasis in both business and design research and practice [69]. This shift is attributable to the role that business models play in determining a product's impact on customer success [70] and its environmental footprint [71]. Moreover, design is increasingly recognized for its potential to facilitate the transition of broader ecosystems towards circular cities, achieved through the redesign of the products and business models, and the application of design thinking to implement innovative projects [72].

The *principles/mindsets* of design thinking are human centered, future oriented, holistic systemic, collaborative and experimental [15]. Collaborative, experimental, and human

centred principles/mindsets are often recognized as part of the culture of design thinking for development of new products [15]. Holistic systemic and future oriented are recognized as design thinking mentality [20] and less frequently mentioned in this analysis. All these principles are recognized in the critical success factors identified by [23] of the culture dimension like: Ability to handle ambiguous situations (experimental), establish collaboration and cross-functional teams (collaborative), diversity orientation (Holistic systemic), and ability to handle complexity and uncertainty (future oriented) and foster empathy (human centered). Additionally, the collaborative principle is the most recognized in the papers as shown in the blue bar of Figure 3, because of the design process is often co-creative involving frequent interactions with multiple customers and stakeholders [47].

The *criteria* are focused on desirability, feasibility, viability, and sustainability/circularity. The desirability criterion refers to what people need and/or want; feasibility refers to what is doable from a technical, technological and/or operational standpoint; viability refers to what is possible financially and/or economically for the innovating organization [48]. These three criteria are central to design thinking and relevant to circular and sustainable innovation as well [49]. The criteria of feasibility and sustainability/circularity as shown in orange bars of Figure 3, are predominant to build new ideas to pass from the linear production to circular economy [50]. The traditional design thinking tools predominantly build upon feasibility and desirability of new ideas and less on viability (except the business model canvas), or circularity and sustainability, whereas the circular economy specific tools build upon feasibility, viability, and circularity criteria [50].

Innovation phases are summarized into five steps: empathize, define, ideate, prototype and test based on HPI at Stanford (d. school) [51]. This model of design thinking has gained most attention [52] because of its roots in academia for educational purposes [53,54] which facilitates the learning processes of diverse stakeholders like SMEs and large firms for DT implementation. With empathy, designers understand users and their actions [55]. In the definition phase, the collected information is processed, and the challenge is defined [56]. In the ideation phase, rough ideas are developed, while in the prototyping phase, a functional model that helps to verify the design is created [55,56]. The last phase is testing in real conditions that can be carried out at all stages of the process and the purpose is to get feedback based on the prototype [56].

Regarding the 20 *tools* identified in Table A1, most of them (49 %), are used for *test* and *empathize* phases, as shown in green bars of Figure 3. Tools recognized in all phases are Quality tools (Virtual reality), customer side, supplier side, participant observation, interviewing, co-creation, experimentation, focus groups, and building a point of view. Virtual reality tools refer to the application of computer-based digital techniques to simulate the sensation of "transferring" users—or more accurately, their consciousness—to a location different from their actual physical presence. To achieve this, users are immersed in a virtual environment (VE) constructed through three-dimensional computer graphics, which allows them to interact with various elements within this simulated space [57]. Design thinking tools, such as contextual interviews and co-creation with diverse stakeholders, facilitate the development of effective strategies and identification of business opportunities. These tools also support the application of rapid prototyping to concretize organizational visions and strategies [8].

The tool used in *empathize, define, prototype* and *test* phases are customer journey maps, visualization tools that provide the means and opportunity for mapping and understanding the multi-dimensional experiences of a customer when interacting with a business or a product [58]. Tools used in *empathize, ideate*, and *define* phases are stakeholder mapping and stakeholder profiling canvas. In these phases DT integrates live stakeholder engagement providing frequent opportunities for the interpretation of viewpoints and needs to be corrected and re balanced [59]. Stakeholder mapping is a tool that supports the highlighting of less emphasized groups to bring alternative viewpoints, perspectives and areas of need into the horizon of decision makers [7], thus assisting to address the

question regarding 'whom' to empathize with. Stakeholder profiling facilitates the ability to understand the operating context, environment and needs of a given party [60].

The tool used in *empathize, ideate*, and *test* phases is job to be done (JTBD) approach [61] which objectives are to provide understanding about the jobs of each persona, to understand what the key and secondary tasks are and to describe how the firm's products/service fit into the jobs of the stakeholder.

Tools used in *empathize, define,* and *test* phases are empathy map and persona. Persona tool is especially helpful in the early phases of product design [62]. The personas are constantly used to evaluate the ideas and prototypes regarding their needs and pains [63]. Also, empathy map is used to understand behaviors, decision taking and pains/gains of the most important stakeholders to build the customer value proposition [64].

In the *ideate, prototype* and *test* phases the tools Quality Function Deployment (QFD), storyboards, user stories, brainstorming and rapid prototyping are used. The utilization of the QFD tool enables the early integration of 'manufacturability' considerations into the design process, rather than addressing these issues retrospectively after the development of a prototype [65].

Tools recognized in *test* phase are contradiction matrix and environment mapping tool. The use of the contradiction matrix and environmental mapping tools help SMEs to systematically generate innovations in the business model, to reduce the solution space in a structured way and to evaluate the resulting solutions according to their advantages and disadvantages [66].

Figure 4 shows an analysis of degree of co-occurrence of DT tools revealing the tools most frequently used for development of new products and technology.

Figure 4. Degree of occurrence of design thinking tools for development of new product/technology.

The tool most frequently mentioned in the articles is user/customer journey map which is predominantly focus on the principles of user-centred, systemic thinking, collaboration and experimentation with multiple stakeholders and are to a lesser extent on future-orientated. Persona, interviewing and co-creation tools are the second most used tools for prototype development. And the third place occupies Job to be done and participant observation tools.

Finally, the *critical success factors* for an effective implementation of design thinking are summarized in the conceptual framework proposed by [23]. Table 1 was the starting point for doing an absolute frequency analysis detailed in Figure 5, to show the underlying factors recognized for design thinking implementation for product development.

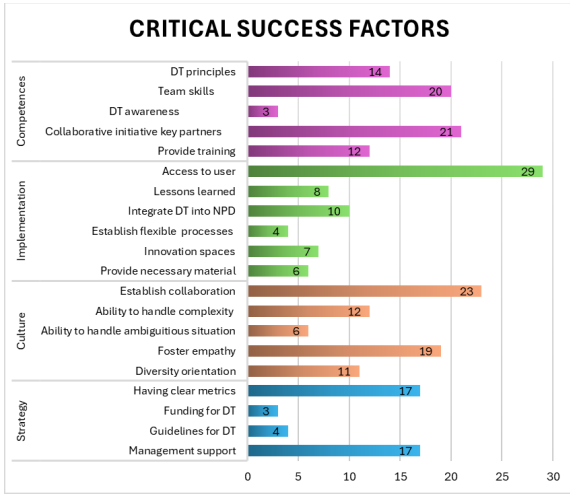

Figure 5. Absolut frequency of critical success factors.

First, *strategy* dimension highlights the factors of management support to have the necessary resources to perform DT related activities [15] and having clear metrics. Second, *culture* dimension emphasizes the CSFs of establish collaboration through cross-functional team to tackle complex and wicked problems through gaining knowledge from many fields and disciplines [31] and fostering empathy with users. This factor means recognizing and understanding other persons' sensations, emotions, thoughts, motives, and personality traits [12,15,73].

Third, the dimension of *implementation* recognizes the factor of access to user, which is the starting point of DT that consists of the observation and analysis of the situation with a focus on the user [12]. Finally, *competence* dimension recognizes the factors of collaborative initiative with key partners like universities and/or research institutes to promote projects [23] and team skills factors to bring different perspectives to project development [39].

5. Discussion

The systematic search for relevant papers has shown that current research regarding implementation of DT in industrial SMEs is limited, i.e., just 30 academic papers have been published so far. Thus, the research knowledge regarding application of DT in the specific context of an industrial SME, such as time and resource limitations, is still limited. Building on the bibliometric analysis of the 30 papers we have identified the central characteristics and CSFs of DT implementation, summarized in Figure 6. The central characteristics for the implementation of DT in enterprises are divided in principles/mindsets, criteria, phases and tools. Additionally, CSFs are divided into four dimensions: strategy, culture, implementation and competences.

Moreover, some of the components in the central characteristics and CSFs occurs more frequently than others indicating their relative importance in an SME context. The key words that are closer to the centre, in figure 6, are those that appear most frequently in the selected papers, applied to the development of new products/technology, in industrial SMEs. While the occurrence of the keywords for characteristics and CSFs are not different from extant research [e.g., 17,18,23], their frequencies indicate an order that is unique to industrial SMEs.

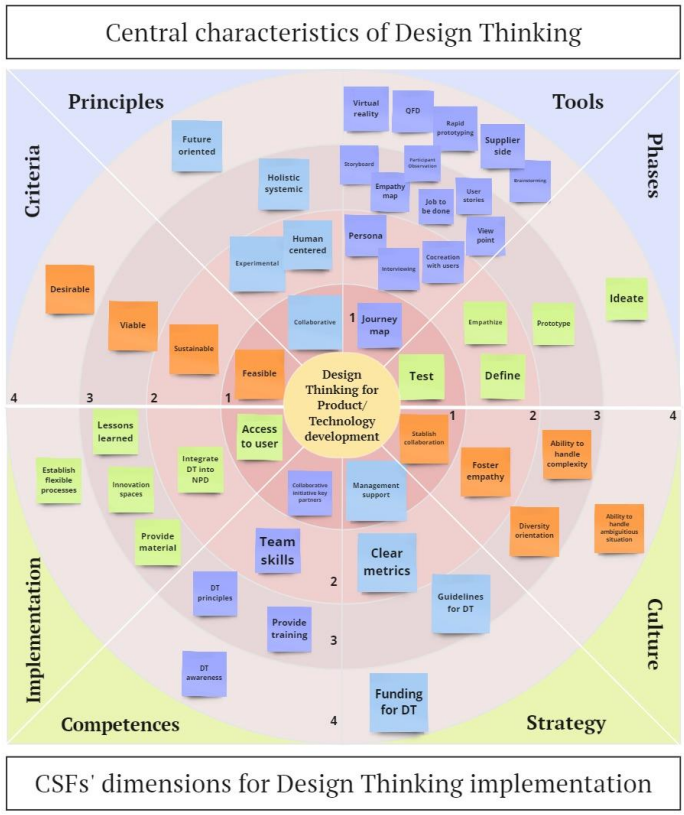

Figure 6. Visual framework of central characteristics and critical success factors for the application of design thinking in industrial SMEs based on the co-word analysis.

The framework detailed in Figure 6 provides a visual representation of the central characteristics and CSFs of DT for effective application in product development processes in industrial SMEs. While the framework gives an overview of all the components of the characteristics and CSFs that are important for effective application of DT, some are especially important, or perhaps challenging, in the SME context as the research mentions these frequently. Compared to extant research on DT application [e.g., 17,18,23] this study shows an order of importance of characteristics and critical success factors. For instance, the most mentioned characteristics and CSFs concern the integration of the user in various ways (e.g., user access, foster empathy, testing, journey maps, personas, human centered) and collaboration with others (e.g., being able to initiate collaboration with key partners, establish a culture of collaboration, co-creation with users, feasibility) indicating that these two application dimensions (integrating users, collaboration with others) might prove to be especially challenging for the SME. The benefits of access to users in various ways smooths a deeper understanding well documented in literature so that technically oriented individuals and teams may derive novel insights for more concerted and user-ori-

ented product ideas by incorporating this perspective [74]. Successful collaborations require trust and respect for users and other key partners in combination with establishing a collaborative organizational culture as suggested by Björk et al. (2014)[75].

The importance of visualization tools such as customer journey maps, storyboards and personas supports a deeper understanding of stakeholder needs and intentions [76]. Manifestations of tangible thoughts, like sketches, diagrams and scenarios inspires and enables communication with users, key partners, internally in the SME as well as with supporting actors such as consultants and universities. Thus, in the same spirit the research-based framework of central characteristics and CSFs as a visual framework. The post it notes in the visual framework makes it also possible to adapt to specific SME contexts and situations, i.e., they may be re-arranged in terms of relevance and importance in development workshops.

6. Conclusions

The research question concerned identifying the central characteristics and critical success factors that are needed to facilitate the effective application of design thinking for product development in industrial SMEs. This in order to construct a framework for application of DT in industrial SMEs that can provide guidance to industrial SME managers and other stakeholders supporting the development of SMEs, i.e., giving an overview of current research as well identifying the most salient issues in application of DT for product development.

After a systematic search for relevant research literature, we performed a bibliometric analysis of titles and abstracts of the selected 30 academic papers. The identified central characteristics of DT application are divided into four aspects: principles, criteria, phases, and tools that enable an effective application for product development in industrial SMEs. Furthermore, the identification of CSFs are divided into four dimensions: culture, competences, strategy, and implementation.

The design thinking phases are empathize, ideate, define, prototype and test. The facilitation criteria include desirability, feasibility, viability and sustainability, and circularity. Finally, the following principles that make design thinking suitable to tackle complex prototype innovation challenges: human-centred, future-oriented, holistic systemic, collaborative, and experimental. In addition, we map twenty tools used in DT.

The analysis indicated that the integration of users in various ways and the competence and culture of collaboration is especially important or perhaps challenging for SMEs to master. In the spirit of DT, we present the research-based framework in visual form, figure 6 above, in order to be used as a visual tool for SME managers and supporting actors in the process of applying DT in their product development process.

7. Limitations and future research

As discussed above, DT in industrial SMEs is an emerging topic, and one in need of further study, because of the ambiguity surrounding the way it is implemented, utilised, and discussed in the specific context of SMEs. Our study has some limitations which warrants further research. First, the framework is based on the 30 selected research papers. Our way of identifying relevant papers, such the database used (Scopus) the search keywords and the snowballing, could result in relevant papers being missed in the selection of papers. Thus, future bibliometric analysis or systematic reviews could complement with other databases and keywords. Second, we have used bibliometric analysis of titles and abstract fields to identify central characteristics and CSFs. Even though this is a standard analytical tool there is always a component of judgement in these types of analysis. Thus, other analytical tools might be used in future reviews to check the robustness of our findings. Third, the research-based framework has been presented in visual form to give a summary and overview of the research field, with the aim to facilitate use in workshops with industrial SME managers and other stakeholders when intending to apply DT or

struggling with its application. However, we have not tested the visual framework in workshops with SMEs or other stakeholders. Thus, future research should test this and other similar frameworks in workshops to validate its value and effects.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure 1: Research method; Figure 2: Visualization of DT characteristics based on co-word analysis; Figure 3: Absolut frequency of central characteristics in DT; Figure 4: Degree of occurrence of design thinking tools for development of new product/technology; Figure 5: Visualization of critical success factors based on co-word analysis Figure 6: Visual framework of central characteristics and critical success factors for the application of design thinking in industrial SMEs based on the co-word analysis. Table A1: Central characteristics of design thinking for development of Technology for SMEs; Table 2: Overview of the identified critical success factors.

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Data Availability Statement: Some data is unavailable due to privacy or ethical restrictions of permission to publish from the copyright holder for any previously published content.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Appendix A

Table A1. Central characteristics of design thinking for development of technology for SMEs.

			Principles					Criteria				Phases					Levels of innovation			Tools	Critical Factors			
N	Year	References (in chronological order)	Human centered	Future oriented	Holistic systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability - circularity	Empathize	Ideate	Define	Prototype	Test	Product - Technology	Business models - Value chain	Ecosystems	Design Thinking tools	Strategy	Culture	Implementation	Competences
1	2023	Gao, B., & Yu, K. (2023). Knowledge exchange in SMEs service innovation with design thinking. Management Decision, 61(7), 2029-2049.https://doi.org/10.1108/MD-06-2022-0795	x			x			x	x	x						x	x		N/A	Management support	Establish collaboration	Access to user	*Collaborative initiative key partners *DT principles
2	2023	Baumkötter, B., Ellenbürger, J., Glemser, M., Raschi, M., Reinschmiedt, L., Schaller, J., & Palm, D. (2023). Neue Produkte erfordern neue Denkweisen zur Einführung: Entwicklung eines neuartigen Markteinführungskonzeptes. Zeitschrift für wirtschaftlichen Fabrikbetrieb, 118(4), 232-236. https://doi.org/10.1515/zwf-2023-1048	x			x	x				x						x			N/A	Management support	Establish collaboration	*Access to user *Integrate DT into NPD	DT principles
3	2023	Rittershaus, P., Renner, M., & Aryan, V. (2023). A conceptual methodology to screen and adopt circular business models in small and medium scale enterprises (SMEs): A case study on child safety seats as a product service system. Journal of Cleaner Production, 390, 136083.			x	x	x				x					x		x		*Contradiction matrix	*Guidelines for DT *Clear Metrics	Establish collaboration	Access to user	Collaborative initiative key partners
					x	x	x				x					x		x		*Environment mapping tool				
4	2022	Storm, J., & Smith, A. (2022). Empathize with Whom? Adopting a Design Thinking Mind-Set to Stimulate Sustainability Initiatives in Chinese SMEs. Sustainability, 15(1), 252.	x			x	x				x	x	x	x					x	*Stakeholder Mapping,	Management support	*Diversity orientation *Foster empathy	Access to user	*Collaborative initiative key partners. *Team skills *DT principles
			x			x	x				x	x	x	x				x	*Stakeholder Profiling Canvas				
5	2022	Starzyńska, B., Kujawińska, A., Górski, F., & Buń, P. (2022). VIRTUAL QUALITY TOOLBOX AS AN INNOVATIVE SOLUTION SUPPORTING LIFELONG LEARNING. International Journal for Quality Research, 16(4).	x			x	x	x				x	x	x	x	x	x		x	*Quality tools like VR (Virtual reality)	Having clear metrics	Foster empathy	*Access to user *Provide necessary material	*Provide training. *Team skills
6	2021	Paay, J., Kuys, B., & Taffe, S. (2021). Innovating product design through university-industry collaboration: Codesigning a bushfire rated skylight. Design Studies, 76, 101031.				x	x		x			x		x	x	x	x			**Customer journey maps,**	Management support	*Diversity orientation *Foster empathy *Establish collaboration	*Access to user *Provide necessary material *Innovation spaces	*Collaborative initiative key partners. *Team skills
						x	x		x				x		x	x	x			*Storyboards				
						x	x		x			x		x		x	x			**Persona**				
7	2021	Whelan, L., Kiernan, L., Morrissey, K., & Deloughry, N. (2021, May). Measuring the success factors of strategic design implementation. In 2021 IEEE Technology & Engineering Management Conference-Europe (TEMSCON-EUR) (pp. 1-6). IEEE.							x	x							x	x		N/A	Having clear metrics	*Diversity orientation *Establish collaboration	Provide necessary material	*Collaborative initiative key partners. *Team skills
8	2020	Lugnet, J., Ericson, Å., & Wenngren, J. (2020). Innovation supports for small-scale development in rural regions: a create, build, test and learn approach. International Journal of Product Development, 24(1), 30-42.			x	x	x										x			N/A	*Management support *Guidelines for DT	Foster empathy	*Access to user *Provide necessary material *Lessons learnt	*Provide training. *Team skills
9	2020	Melazzini, M., Campodall'Orto, S., Carella, G., Vignati, A., & Zurlo, F. (2020). Design Thinking Methods to Activate Co-creation Process Among Policymakers, Creative Industries and SMEs. In Proceedings of the II International Triple Helix Summit 2 (pp. 263-277). Springer International Publishing.		x	x	x		x	x	x									x	N/A	*Management support *Ensure funding *Having clear metrics	*Diversity orientation *Foster empathy *Establish collaboration	*Access to user *Provide necessary material *Lessons learnt	*Provide training. *Collaborative initiative key partners *Team skills

			Principles					Criteria				Phases					Levels of innovation			Tools	Critical Factors			
N	Year	References (in chronological order)	Human centered	Future oriented	Holistic systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability - circularity	Empathize	Ideate	Define	Prototype	Test	Product - Technology	Business models - Value chain	Ecosystems	Design Thinking tools	Strategy	Culture	Implementation	Competences
10	2019	Redante, R. C., de Medeiros, J. F., Vidor, G., Cruz, C. M. L., & Ribeiro, J. L. D. (2019). Creative approaches and green product development: Using design thinking to promote stakeholders' engagement. Sustainable Production and Consumption, 19, 247-256.			x	x	x		x								x			N/A	Management support	*Foster empathy *Establish collaboration	*Access to user *Integrate DT into NPD	*Collaborative initiative key partners *DT principles
11	2019	Félix, M. J., Gonçalves, S., Jimenez, G., & Santos, G. (2019). The contribution of design to the development of products and manufacturing processes in the Portuguese industry. Procedia Manufacturing, 41, 1055-1062.		x	x	x	x		x								x			N/A	Management support	Ability to handle ambiguitious situation	Access to user	Team skills
12	2018	Heck, J., Rittiner, F., Meboldt, M., & Steinert, M. (2018). Promoting user-centricity in short-term ideation workshops. International Journal of Design Creativity and Innovation, 6(3-4), 130-145.	x		x	x	x					x		x		x	x	x		* Persona	Having clear metrics	*Diversity orientation *Foster empathy *Establish collaboration	*Access to user * Innovation spaces *Integrate DT into NPD	*Collaborative initiative key partners *DT principles *Team skills
13	2018	O'Gorman, P., Morgan, M., & Van Merkom, R. (2018, December). Using QFD to Normalize a Culture of Innovation in an Engineering SME. In 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 307-310). IEEE.					x		x				x		x	x	x			*QFD	Management support	Establish collaboration	*Access to user *Establish flexible processes	*Collaborative initiative key partners
14	2016	Roach, D. C., Ryman, J. A., & Makani, J. (2016). Effectuation, innovation and performance in SMEs: an empirical study. European Journal of Innovation Management, 19(2), 214-238.					x	x			x						x	x		N/A	Having clear metrics	*Ability to handle ambiguitious situation *Ability to handle complexity	Access to user	Collaborative initiative key partners
15	2016	Gerlitz, L.; Hack, A.; Prause, G. (2016). An Integrated Design Management Concept: Creating Innovative Space for Emergent SMEs and Value for Knowledge Absorbers. Journal of Entrepreneurship and Innovation in Emerging Economies, 2(1), 38–55. doi:10.1177/2393957515619717					x		x	x	x						x	x		N/A	*Management support *Having clear metrics	*Diversity orientation *Ability to handle complexity *Establish collaboration	*Access to user *Innovation spaces *Integrate DT into NPD	*Provide training. *Team skills
16	2016	West, S., & Di Nardo, S. (2016). Creating product-service system opportunities for small and medium size firms using service design tools. Procedia CIRP, 47, 96-101.					x				x	x		x		x	x			*Empathy map,	Having clear metrics	*Foster empathy *Ability to handle complexity	Access to user	Team skills
							x				x	x	x			x	x			* Job to be done,				
							x				x	x	x	x	x	x	x			*Customer side				
							x				x	x	x	x	x	x	x			*Supplier side				
17	2015	Nil Gulari, M., & Fremantle, C. (2015). Are design-led innovation approaches applicable to SMEs?. In DS 82: Proceedings of the 17th International Conference on Engineering and Product Design Education (E&PDE15), Great Expectations: Design Teaching, Research & Enterprise, Loughborough, UK, 03-04.09. 2015 (pp. 556-561).	x		x	x			x	x							x			N/A	Management support	Ability to handle complexity and uncertainty	Access to user	Collaborative initiative key partners

			Principles					Criteria				Phases					Levels of innovation			Tools	Critical Factors			
N	Year	References (in chronological order)	Human centered	Future oriented	Holistic systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability - circularity	Empathize	Ideate	Define	Prototype	Test	Product - Technology	Business models - Value chain	Ecosystems	Design Thinking tools	Strategy	Culture	Implementation	Competences
18	2023	Rösch, N., Tiberius, V., & Kraus, S. (2023). Design thinking for innovation: context factors, process, and outcomes. European Journal of Innovation Management, 26(7), 160-176.	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		*Participant observation,	*Management support *Guidelines for DT	*Foster empathy *Ability to handle ambiguitious situation *Ability to handle complexity *Establish collaboration	*Access to user *Integrate DT into NPD *Lessons learnt	*Collaborative initiative key partners *DT principles *Team skills *Provide training
			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		* Interviewing,				
			x		x	x	x	x	x	x	x	x		x	x	x	x	x		* Journey mapping				
			x		x	x	x	x	x	x	x	x	x			x	x	x		* Job-to-be-done analysis				
19	2022	Manzke, J. (2022). Design Thinking for Innovation Within Manufacturing SMEs: A Multiple Case Study (Doctoral dissertation, Walden University).	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	* Observation, interviews	*Management support *Having clear metrics	*Foster empathy *Ability to handle complexity and uncertainty *Establish collaboration	*Access to user *Establish flexible processes. *Innovation spaces	*Provide training. *Collaborative initiative key partners *Team skills *DT principles
			x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	* Customer journey mapping, co-creation				
			x		x	x	x	x	x	x	x		x			x	x	x	x	*Brainstorming, co-creation				
			x		x	x	x	x	x	x	x		x			x	x	x	x	*Experimentation rapid prototyping				
20	2022	Nakata, C., & Bahadir, S. C. (2022). Managing design for innovative new products and services. Journal of Business Strategy, 43(5), 275-282.	x			x	x			x							x			N/A	Management support	Establish collaboration	*Access to user *Lessons learnt	Provide training.
21	2022	Eisenbart, B., Bouwman, S., Voorendt, J., McKillagan, S., Kuys, B., & Ranscombe, C. (2022). Implementing design thinking to drive innovation in technical design. International Journal of Design Creativity and Innovation, 10(3), 141-160.	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		User research (including interviews and/or focus groups)	Having clear metrics	*Diversity orientation *Foster empathy *Ability to handle complexity and uncertainty *Establish collaboration	*Establish flexible processes. *Access to user *Integrate DT into NPD	*Collaborative initiative key partners *Team skills *DT principles
			x	x	x	x	x		x	x	x	x		x	x	x	x	x		* User/customer journey mapping,				
			x	x	x	x	x		x	x	x	x		x		x	x	x		* Personas				
			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		*Co-creation with users,				
			x	x	x	x	x		x	x	x		x		x	x	x	x		*User stories and,				
			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		*Building a point of view.				
22	2022	Moretti, D. M., Baum, C. M., Wustmans, M., & Bröring, S. (2022). Application of journey maps to the development of emergent sustainability-oriented technologies: Lessons for user involvement in agriculture. Business Strategy & Development, 5(3), 209-221.	x		x	x	x	x	x		x	x		x	x	x	x	x		* Journey map	Having clear metrics	*Diversity orientation *Ability to handle complexity and uncertainty *Establish collaboration	*Access to user *Integrate DT into NPD	*Collaborative initiative key partners *Team skills
23	2021	Starostka, J., Evald, M. R., Clarke, A. H., & Hansen, P. R. (2021). Taxonomy of design thinking facilitation. Creativity and Innovation Management, 30(4), 836-844.	x			x	x	x									x	x		N/A	Having clear metrics	*Foster empathy *Establish collaboration	*Access to user	*Collaborative initiative key partners *Team skills *DT principles
24	2020	Nakata, C. (2020). Design thinking for innovation: Considering distinctions, fit, and use in firms. Business horizons, 63(6), 763-772.	x			x	x		x	x							x	x		N/A	Having clear metrics	*Foster empathy *Ability to handle complexity and uncertainty *Establish collaboration	*Access to user	*Collaborative initiative key partners *Team skills
25	2020	Wrigley, C., Nusem, E., & Straker, K. (2020). Implementing design thinking: Understanding organizational conditions. California Management Review, 62(2), 125-143.	x			x		x	x	x							x	x		N/A	*Management support *Having clear metrics	*Foster empathy *Diversity orientation *Establish collaboration	*Access to user *Integrate DT into NPD *Innovation spaces	*Provide training *Collaborative initiative key partners *DT awareness *Team skills *DT principles

			Principles					Criteria				Phases					Levels of innovation			Tools	Critical Factors			
N	Year	References (in chronological order)	Human centered	Future oriented	Holistic systemic	Collaborative	Experimental	Desirability	Feasibility	Viability	Sustainability - circularity	Empathize	Ideate	Define	Prototype	Test	Product-Technology	Business models-Value chain	Ecosystems	Design Thinking tools	Strategy	Culture	Implementation	Competences
26	2020	Savić, M. (2020). Key resources in small and medium enterprises for business model innovation.	x			x	x		x	x	x						x	x	x	N/A	Management support	*Foster empathy *Establish collaboration	Access to user	*Provide training *Collaborative initiative key partners
27	2019	De Paula, D., Dobrigkeit, F., & Cormican, K. (2019, July). Doing it right-critical success factors for design thinking implementation. In Proceedings of the Design Society: International Conference on Engineering Design (Vol. 1, No. 1, pp. 3851-3860). Cambridge University Press.	x		x	x	x				x						x			N/A	*Management support *Guidelines for DT *Funding for DT *Having clear metrics	*Diversity orientation *Foster empathy *Ability to handle ambiguitious situation *Ability to handle complexity and uncertainty *Establish collaboration	*Provide material *Innovation spaces *Establish flexible processes. *Integrate DT into NPD *Lessons learnt *Access to user	*Provide training *Collaborative initiative key partners *DT awareness *Team skills *DT principles
28	2018	Lugnet, J., Wenngren, J., & Ericson, Å. (2018). ADDRESSING TEAM BASED INNOVATION FOR SMALL FIRMS-CREATE, BUILD, TEST &LEARN. In DS 92: Proceedings of the DESIGN 2018 15th International Design Conference (pp. 849-856).				x	x										x			N/A	Having clear metrics	*Foster empathy *Ability to handle ambiguitious situation *Ability to handle complexity and uncertainty *Establish collaboration	*Lessons learnt *Access to user	*Provide training *Team skills *DT principles
29	2016	Carlgren, L., Elmquist, M., & Rauth, I. (2016). The challenges of using design thinking in industry–experiences from five large firms. Creativity and Innovation Management, 25(3), 344-362.	x		x	x	x		x	x	x						x	x		N/A	Having clear metrics	*Diversity orientation *Foster empathy *Ability to handle complexity and uncertainty *Establish collaboration	*Integrate DT into NPD *Lessons learnt *Access to user	*Provide training *Collaborative initiative key partners *DT awareness *Team skills *DT principles
30	2011	Malins, J. P. (2011). Innovation by design: using design thinking to support SMEs.				x					x						x	x		N/A	Funding for DT	*Foster empathy *Ability to handle ambiguitious situation *Establish collaboration	*Innovation spaces *Lessons learnt *Access to user	DT principles

References

1. 1. Bonakdar A, Gassmann O. Design Thinking for Revolutionizing Your Business Models. *Design Thinking for Innovation: Research and Practice* 2016:57–66.
2. 2. Martin B,, Hanington B. Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. *Rockport Publishers* 2012.
3. 3. Klewitz J, Hansen EG. Sustainability-oriented innovation of SMEs: a systematic review. *J Clean Prod* 2014;**65**:57–75.
4. 4. De Jong JPJ, Marsili O. The fruit flies of innovations: A taxonomy of innovative small firms. *Res Policy* 2006;**35**:213–29.
5. 5. Kenney M. The Temporal Dynamics of Knowledge Creation in the Information Society., 2001.
6. 6. Andreassen TW, Lervik-Olsen L, Calabretta G. Deriving Valuable Innovations: A Trend Spotting Approach FORTHCOMING AT MANAGING SERVICE QUALITY., 2015.
7. Geissdoerfer M, Bocken NMP, Hultink EJ. Design thinking to enhance the sustainable business modelling process e A workshop based on a value mapping process. 2016, DOI: 10.1016/j.jclepro.2016.07.020.
8. Elsbach KD, Stigliani I. Design Thinking and Organizational Culture: A Review and Framework for Future Research. *J Manage* 2018;**44**:2274–306.
9. Micheli P, Perks H, Beverland MB. Elevating Design in the Organization. *Journal of Product Innovation Management* 2018;**35**:629–51.
10. Cousins B. Design thinking: Organizational learning in VUCA environments. . *Academy of Strategic Management Journal* 2018;**17**:1–18.
11. Ferrara M, Di Milano P, Chiara Lecce I. "Design for Enterprises": Developing European SMEs capabilities for design-driven innovation. *Markets, Globalization & Development Review* 2020;**4**, DOI: 10.23860/MGDR-2019-04-02-07.

12. Brown T. Design Thinking. In Harvard Business Review. 2008;**86**:84–92.
13. Martin R. The Design of Business: Why Design Thinking Is the next Competitive Advantage - DESIGNING A BUSINESS. 2009.
14. Acklin C. Design-Driven Innovation Process Model. *Design Management Journal* 2010;**5**:50–60.
15. Carlgren L, Rauth I, Elmquist M. Framing Design Thinking: The Concept in Idea and Enactment. *Creativity and Innovation Management* 2016;**25**:38–57.
16. Best K. Design Management: Managing Design Strategy. *Process and Implementation, AVA publishing* 2006.
17. Wölbling A, Krämer K, Buss CN *et al.* Design Thinking: An Innovative Concept for Developing User-Centered Software. *Management for Professionals* 2012;**Part F393**:121–36.
18. Brenner W, Uebernickel F, Abrell T. Design Thinking as Mindset, Process, and Toolbox. *Design Thinking for Innovation: Research and Practice* 2016:3–21.
19. Stickdorn M, Schneider J, Andrews K *et al.* This is service design thinking: Basics, tools, cases. *Hoboken, NJ: Wiley* 2011;**1**.
20. Hassi L, Laakso M. DESIGN THINKING IN THE MANAGEMENT DISCOURSE: DEFINING THE ELEMENTS OF THE CONCEPT. *In 18th International Product Development Management Conference, IPDMC* 2011:1–14.
21. Eisenbart B, Bouwman S, Voorendt J *et al.* Implementing design thinking to drive innovation in technical design. *International Journal of Design Creativity and Innovation* 2022;**10**:141–60.
22. Eybers S and GA. "Identifying Critical Success Factors for Business Intelligence Systems." *The European Conference on Information Systems Management, Academic Conferences International Limited*. 2015, 77–84.
23. de Paula D, Dobrigkeit F, Cormican K. Doing it right - Critical success factors for design thinking implementation. *Proceedings of the International Conference on Engineering Design, ICED*. Vol 2019-August. Cambridge University Press, 2019, 3851–60.
24. Holloway M. How tangible is your strategy? How design thinking can turn your strategy into reality. Kumar V (ed.). *Journal of Business Strategy* 2009;**30**:50–6.
25. Rosensweig RR. More than Heroics: Building Design as a Dynamic Capability. *Design Management Journal* 2011;**6**:16–26.
26. Carlgren L, Elmquist M, Rauth I. The Challenges of Using Design Thinking in Industry – Experiences from Five Large Firms. *Creativity and Innovation Management* 2016;**25**:344–62.
27. Kimbell L. Beyond design thinking: Design-as-practice and designs-in-practice. 2009.
28. Liedtka J. Learning to use design thinking tools for successful innovation. *Strategy and Leadership* 2011;**39**:13–9.
29. Lockwood T. Transition: How to Become a More Design-Minded Organization. *Des Manage Rev* 2009;**20**:28–37.
30. Dunne D, Martin R, Rotman JL. Design Thinking and How It Will Change Management Education: An Interview and Discussion. *Academy of Management Learning & Education* 2006;**5**:512–23.
31. Gloppen J. Perspectives on Design Leadership and Design Thinking and How They Relate to European Service Industries. *Design Management Journal - Des Manag J* 2009;**4**:33–47.
32. Sato S, Lucente S, Mrazek D *et al.* D E V E LO PM E N T. *Des Manage Rev* 2010;**21**:44–52.
33. Boland, Collopy F. Design matters for management. *Managing as Designing*. 2004, 3–18.
34. Cooper R, Junginger S, Lockwood T. Design Thinking and Design Management: A Research and Practice Perspective. *Des Manage Rev* 2009;**20**:46–55.
35. Dew N. Abduction: a pre-condition for the intelligent design of strategy. *PAGE 38 j JOURNAL OF BUSINESS STRATEGY j* 2007;**28**:38–45.
36. Micheli P, Jaina J, Goffin K *et al.* Perceptions of industrial design: The "means" and the "ends." *Journal of Product Innovation Management* 2012;**29**:687–704.
37. Carlgren L, Elmquist M, Rauth I. Design Thinking: Exploring Values and Effects from an Innovation Capability Perspective. *The Design Journal* 2014;**17**:403–23.
38. Ward A, Runcie E, Morris L. Embedding innovation: Design thinking for small enterprises. *Journal of Business Strategy* 2009;**30**:78–84.
39. Seidel VP, Fixson SK. Adopting Design Thinking in Novice Multidisciplinary Teams: The Application and Limits of Design Methods and Reflexive Practices*. 2013, DOI: 10.1111/jpim.12061.
40. Donthu N, Kumar S, Mukherjee D *et al.* How to conduct a bibliometric analysis: An overview and guidelines. *J Bus Res* 2021;**133**:285–96.
41. Klarin A. How to conduct a bibliometric content analysis: Guidelines and contributions of content co-occurrence or co-word literature reviews. *Int J Consum Stud* 2024;**48**, DOI: 10.1111/ijcs.13031.
42. Börner K, Chen C, Boyack KW. Visualizing Knowledge Domains 1. *Annu Rev Inf Sci Technol* 2003.
43. Chen X, Zou D, Xie H. Fifty years of British Journal of Educational Technology: A topic modeling based bibliometric perspective. *British Journal of Educational Technology* 2020;**51**:692–708.
44. van Eck NJ, Waltman L. Visualizing Bibliometric Networks. *Measuring Scholarly Impact* 2014:285–320.
45. Baier-Fuentes H, Cascón-Katchadourian J, Sánchez ÁM *et al.* A Bibliometric Overview of the International Journal of Interactive Multimedia and Artificial Intelligence. *International Journal of Interactive Multimedia and Artificial Intelligence* 2018;**5**:9.
46. Melazzini M, Campodall'Orto S, Carella G *et al.* Design thinking methods to activate co-creation process among policymakers, creative industries and SMEs. *Lecture Notes in Civil Engineering* 2020;**43**:263–77.
47. Guldmann E, Bocken NMP, Brezet H. *A Design Thinking Framework for Circular Business Model Innovation*., 2019.
48. Calabretta G, Gemser G,, Karpen I. Strategic design: eight essential practices every strategic designer must master. . *Bis publishers* 2016.

49. Baldassarre B, Konietzko J, Brown P *et al.* Addressing the design-implementation gap of sustainable business models by prototyping: A tool for planning and executing small-scale pilots. *J Clean Prod* 2020;**255**:120295.
50. Bocken N, Baldassarre B, Keskin D *et al.* Design thinking tools to catalyse sustainable circular innovation. *Circular X-Experimentation with Circular Service Business Models View Project Online Platforms and the Circular Economy View Project*. 2023, 1–36.
51. Henriksen D, Richardson C, Mehta R. Design thinking: A creative approach to educational problems of practice. *Think Skills Creat* 2017;**26**:140–53.
52. Kwon J, Choi Y, Hwang Y. Enterprise Design Thinking: An Investigation on User-Centered Design Processes in Large Corporations. *Designs 2021, Vol 5, Page 43* 2021;**5**:43.
53. Framework for Innovation: Design Council's Evolved Double Diamond. . *Available online: https://www.designcouncil org.uk/our-work/skills-learning/tools-frameworks/framework-for-innovation-design-councils-evolved-double-diamond* 2022.
54. Dorst K. The core of "design thinking" and its application. *Des Stud* 2011;**32**:521–32.
55. Pap M, Vdović R, Baletić B. Design Thinking metoda u znanstvenom istraživanju, edukaciji i poslovnoj praksi. *Prostor* 2019;**27**:334–47.
56. Antoljak V, Kosović M. Design thinking za nedizajnere – kako riješiti poslovne probleme i uspješno inovirati. *Zagreb: Školska knjiga (in Croatian)* 2018.
57. Starzyńska B, Kujawińska A, Górski F *et al.* VIRTUAL QUALITY TOOLBOX AS AN INNOVATIVE SOLUTION SUPPORTING LIFELONG LEARNING. *International Journal for Quality Research* 2022;**16**:1013–28.
58. Lemon KN,, Verhoef PC. Understanding customer experience throughout the customer journey. *J Mark* 2016;**80**:69–96.
59. Luka I. Design Thinking in Pedagogy. *The Journal of Education, Culture, and Society* 2014;**5**:63–74.
60. Wolfe RA, Putler DS. How Tight Are the Ties that Bind Stakeholder Groups? *https://doi.org/101287/orsc13164544* 2002;**13**:64–80.
61. Bettencourt LA, Ulwick AW. *The Customer-Centered Innovation Map*., 2008.
62. Long F. Real or imaginary: The effectiveness of using personas in product design. . *In Proceedings of the Irish Ergonomics Society annual conference* 2009;**14**:1–10.
63. Heck J, Rittiner F, Meboldt M *et al.* Promoting user-centricity in short-term ideation workshops. *International Journal of Design Creativity and Innovation* 2018;**6**:130–45.
64. West S, Di Nardo S. Creating Product-service System Opportunities for Small and Medium Size Firms Using Service Design Tools. *Procedia CIRP*. Vol 47. Elsevier B.V., 2016, 96–101.
65. P. O'Gorman, M. Morgan, R. Van Merkom. Using QFD to Normalize a Culture of Innovation in an Engineering SME. 2018.
66. Rittershaus P, Renner M, Aryan V. A conceptual methodology to screen and adopt circular business models in small and medium scale enterprises (SMEs): A case study on child safety seats as a product service system. *J Clean Prod* 2023;**390**, DOI: 10.1016/j.jclepro.2023.136083.
67. Konietzko J, Bocken N, Hultink EJ. A tool to analyze, ideate and develop circular innovation ecosystems. *Sustainability (Switzerland)* 2020;**12**, DOI: 10.3390/su12010417.
68. Rashid A, Asif FMA, Krajnik P *et al.* Resource conservative manufacturing: An essential change in business and technology paradigm for sustainable manufacturing. *J Clean Prod* 2013;**57**:166–77.
69. Diehl JC, Christiaans H. Product Service Systems: The Future for Designers? The Changing Role of the Industrial Designer. In Proceedings of the International Design Congress of KSDS and Adada with Cumulus, Gwangju, Korea. *Carel Diehl on* 2015;**21**:17–23.
70. Chesbrough H. Business Model Innovation: Opportunities and Barriers. *Long Range Plann* 2010;**43**:354–63.
71. Tukker A. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Bus Strategy Environ* 2004;**13**:246–60.
72. Prendeville S, Cherim E, Bocken N. Circular Cities: Mapping Six Cities in Transition. *Environ Innov Soc Transit* 2018;**26**:171–94.
73. Glen R, Suciu C, Baughn CC *et al.* Teaching design thinking in business schools. *The International Journal of Management Education* 2015;**13**:182–92.
74. Garbuio M, Dong A, Nidthida LIN *et al.* Demystifying the Genius of Entrepreneurship: How Design Cognition Can Help Create the Next Generation of Entrepreneurs. *https://doi.org/105465/amle20160040* 2018;**17**:41–61.
75. Björk J, Karlsson MP, Magnusson M. Turning ideas into innovations - introducing demand-driven collaborative ideation. *International Journal of Innovation and Regional Development* 2014;**5**:429.
76. Paay J, Kuys B, Taffe S. Innovating product design through university-industry collaboration: Codesigning a bushfire rated skylight. *Des Stud* 2021;**76**, DOI: 10.1016/j.destud.2021.101031.

Paper II

Critical factors of Design Thinking Implementation for Design of prototypes for SMEs of Cluster initiatives. Cases from Bolivia.

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Abstract:

This research seeks to identify critical factors that influence the success to implementing design thinking in the process of prototype design within SMEs clusters in developing countries like Bolivia. The determinants of design thinking implementation are generally underexplored, therefore exhibiting its innovative point and contributing to the relevant debate in the field of design, as well as organization management. The qualitative methodology applied are multiple case studies of five design experiences of SMEs Clusters facilitated by a public university. The findings are divided in success and impeding factors of Design Thinking implementation. Success factors are fostering empathy, experimentation, and iteration, establishing collaboration and cross-functional teams and collaborative initiative. Impeding factors are time constraints, insecure management support and resource constraints. Additionally, strategies to improve Design Thinking implementation are set functions for management of design projects, time optimization, flexible payment plans, strengthen collaborations, use of DT tools and digital simulation software's.

Keywords: Design Thinking, Prototypes, critical factors, university-industry collaboration**.**

1 Introduction

In recent years, design professionals recognize that new forms of design are developing and transforming the way enterprises create value with shifted focus of innovation from product-centric to user experience-focused (Naiman, 2019). This is especially evident when design can shape satisfying solutions to wicked or ill-defined problems (Li and Bacete, 2022) such as prototype design for non-developed countries, where companies are mostly micro-, small- and medium-sized enterprises, the adoptions of advanced manufacturing technologies (AMTs) and quality management (QM) are much less extensive (Bello Pintado et al., 2015) like the case of Bolivia.

Author

In Bolivia, the design of prototypes to support Small and Medium Sized enterprises (SMEs) occurs through university-industry collaborative spaces known as Cluster Initiatives (CIs) coordinated by a Unit of Technology Transfer (UTT) from a public university, such as the Universidad Mayor de San Simon (UMSS). In these spaces, Design Thinking phases has been applied since 2021, as a structure that supports the management level in the development of strategies (Ben Mahmoud-Jouini et al., 2016; Cagnin, 2018; Knight et al., 2020) carry out effective prototype design innovations (Malins, 2011). This is mainly due to previous experiences with prototypes that showed only 54% effectiveness (Arandia et al., 2020), which prompted the Unit of Technology Transfer to use Design Thinking phases due to their proximity to the prototype development stages in one of the Cluster initiatives such as the Cochabamba Food Cluster (Arandia and Olivares, 2020).

In that sense the academia, which is a central actor within cluster initiatives, is looking on how design thinking can be applied within product- technology innovation to support socio-productive sector like SMEs. Since the integration of DT process into the product development strategy will improve the competitive position of an enterprise (Best, 2006).

Although there are studies that provide insight into the underlying factors for an effective implementation of Design Thinking (de Paula et al., 2019) that synthesize some issues on how to facilitate a DT implementation (Liedtka, 2015) and how DT contributes to organizations (Carlgren et al., 2014). The determinants of design thinking implementation are still generally underexplored. Despite there is a study of the identification of the critical factors for the implementation of Design Thinking proposed by De Paula et al., (2019), studies with empirical validation of these factors don't exist in the context of university-industry collaborative spaces for the design of prototypes to support SMEs of countries with limited resources.

In this sense, this research seeks to identify critical factors (success and impeding factors) that influence the success to implementing design thinking in the process of prototype design within SMEs Cluster initiatives in developing countries like Bolivia.

By this way the learning lessons from previous projects of developed prototypes are essential to guide a comprehensively integration of DT into the product development process to achieve the project objectives.

Therefore, the aim of this study is to identify the critical factors (success and impeding factors) of Design Thinking implementation for the design of prototypes in the context of SMEs Cluster initiatives.

Thus, the research is guided by the following research questions:

RQ1. What are the critical factors of Design Thinking implementation identified in prototypes design experiences of SMEs cluster initiatives?

RQ2. How can the DT processes be improved based on the critical factors identified in these design experiences of SMEs cluster initiatives?

Based on these, an exploratory case studies of prototypes developed by cluster initiatives for SMEs in Bolivia was conducted.

2. Theoretical Framework

Cluster initiatives.

In Bolivia, important efforts are being promoted to link local technological development capabilities with Small and Medium sized enterprises (SMEs) through Cluster Initiatives (CIs) organized by a public university, such the case of Universidad Mayor de San Simón (UMSS).Lindqvist et al., (2003) defined Cluster Initiatives (CIs) as organized efforts to increase the growth and competitiveness of clusters within a region, involving firms, government and/or the research community.
In that sense, the UMSS through the Program of Innovation managed by the Unit of Technology Transfer (UTT) has adopted in 2007 a clustering strategy (university, business, government) in prioritized productive sectors to improve university-industry collaboration under a systemic approach (Arandia et al., 2020). The actions developed from UMSS' Program of innovation can be interpreted as approaches of 'developmental university'. This approach is very important because it reveals much better the vision that the university through the Unit of Technology Transfer has regarding fostering interactive learning processes oriented to innovation. It also allows to analyse and plan better the activities being carried out by the university through the UTT. This conception search solving the problems faced by the less favoured population such as SMEs, through the production of socially inclusive knowledge (Brundenius et al., 2009).

In that sense, the University-Industry Collaboration through Clusters brings benefits mainly for SMEs, because of the common challenge of scarcity of economic resources and technical capabilities which prompts them to seek external assistance through participation in research projects and collaborative knowledge sharing (Ibarra et al., 2020). In that sense, UMSS design researchers provide support to two cluster SMEs, Cochabamba Food Cluster (CFC) and Green Technology Cluster (GTC), through their knowledge and time to innovate in product design and manufacturing processes (Paay et al., 2021) through the design of prototypes.

The first cluster created was the "Food Cluster Cochabamba" in 2008 because of the traditional importance of food sector and beverage in the Cochabamba city (SITAP-UDAPRO, 2015) and high concentrated of research university resources oriented to food campus and its current relevance it currently has in the Development Regional Agenda (Acevedo et al., 2015). And the "Green Technology Cluster" was created in 2021 to answer the requirements of a sector which started to follow a circular economy approach.

In these spaces, the university provides support to SMEs in the development of research projects of design of prototypes of machinery that allows an efficiency growth of firms regarding minimizing the cost, increasing productivity, and reducing time to market of their products (Latifi et al., 2021). In that sense, the aim of designing a prototype is to obtain the documentation with a proposal design of a machinery prototype requested by SMEs with the following information: cost proposal, drawings and simulations of machine function and composition.

A prototype is defined as an approximation of the product along one or more dimensions of interest (Ulrich et al., 2020). In turn, it is as a representation of a design that allows us not only the first verification of the future product, but also to be able to be a valuable instrument for the front end of the design. Prototypes are often used to express a concept (Elverum et al., 2014) as a physical or digital embodiment of critical elements in

the design, and an iterative tool to enhance communication, enable learning, and inform decision-making at any point in the design process (Lauff et al., 2018).

Ulrich et al., (2020) define concept as a description of the form, function, and characteristics of a product that is usually accompanied by a set of specificities.

Regarding the development of prototypes, Kelley and Littman, (2006) state that it is a combination of methods to give physical or visual form to an idea or concept. Other studies emphasize that prototype responds to prototyping strategy. Lack of a prototyping strategy can cause projects to be delayed, go over budget, and therefore the work is not effective (Camburn et al., 2013).

In general, a successful project of design of prototype consists of producing a virtual or physical prototype to test the form, function, and technical characteristics of the product, and simulate the cost and service construction.

Design Thinking

Design thinking (DT) is an iterative process which seeks to understand the user, challenge assumptions, and redefine problems to identify alternative strategies and solutions. At the same time, Design Thinking provides a solution-based approach to solving problems.

Design Thinking combines "empathy for the context of a problem, creativity in the generation of insights and solutions, and rationality in analysing and fitting various solutions to the problem context" (Kelley and Kelley, 2013), by inviting the end user/consumer to be involved in a systematic consideration of the innovation outcome's sustainability performance over the full product life cycle (Buhl et al., 2019).

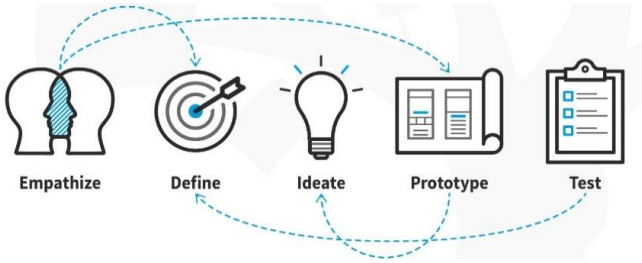
Design Thinking has opened and democratized the process of design to other disciplines and wider problems, rather than just creating physical artefacts, and therefore further aligns design with entrepreneurship (White and Kennedy, 2022). A central proposition of Design Thinking is that it can be helpful for a range of business challenges as those faced by SMEs that exceed the traditional focus of industrial design and should be pursued by non-designers as well as designers (Brown and Katz, 2011).

From a more general perspective, Carlgren et al., (2014) found that incorporating DT into the NPD (New Product Development) process can result in significant cost savings as DT is lauded to reduce redesign work and shorten lead time to development. These benefits stimulated the use of Design Thinking approach within SMEs clusters managed by a public university.

The cluster initiatives adopted the five stages of design thinking defined by the Hasso Plattner Institute of Design at Stanford, as a way of structure the process of prototype design into five steps: empathise, define, ideate, prototype, and test (Siang, 2020). The Figure 1 shows the Design Thinking 5 stages.

Figure 1. Design Thinking: A 5-Stage process. **Source:** Reproduced with permission of Interaction-design.org © Interaction Design Foundation, CC BY-SA 3.0

Title



Stage 1: Empathize — This stage consists of an empathetic understanding of the problem to solve, typically through user research. Empathy is crucial to a human-centred design process such as DT because it allows you to set aside your own assumptions about the world and gain real insight into users and their needs. With empathy, designers understand users and their actions (Pap et al., 2019).

Stage 2: Define — In the definition phase, the collected information is processed, and the challenge is defined (Antoljak and Kosović, 2018). It focusses on analyses the observations and synthesizes them to define the core problems identified. These definitions are called problem statements. You can create personas to help keep your efforts human-centred before proceeding to ideation.

Stage 3: Ideate —This stage consists of generate ideas. The solid background of knowledge from the first two phases means you can start to "think outside the box," look for alternative ways to view the problem and identify innovative solutions to the problem statement you have created. The team starts to develop solutions, ideas and proposals using various techniques to enhance creativity (Dias Daniel, 2016), like Brainstorming.

Stage 4: Prototype — This is an experimental phase. The aim is to identify the best possible solution for each problem found. It consists of producing some inexpensive, scaled-down versions of the product (or specific features found within the product) to investigate the ideas generated. This could simply involve paper prototyping.

Stage 5: Test— The last step is testing in real conditions that can be carried out at all stages of the process and the purpose is to get feedback based on the prototype (Antoljak and Kosović, 2018). Although this is the final phase, design thinking is iterative: Teams often use the results to redefine one or more further problems. So, you can return to previous stages to make further iterations, alterations, and refinements – to find or rule out alternative solutions.

Overall, these stages are a way to structure the design process which contribute to the entire design project, using these sequential steps. The goal throughout is to gain the deepest understanding of the users and what their ideal solution/product would be.

Critical factors

Critical success factors (CSFs) are items or actions that should be present in a particular project or situation to be successful (Eybers, 2015).

For this study, CSFs are those factors crucial to the implementation of DT, in the Bolivian context of SME clustering. The identification of such factors must be considered if institutions want to successfully implement design thinking.

By identifying the CSFs, institutions can take required precautions to elude failures or problematic areas and be able to increase the success rate of implementing DT. From an academic perspective, the study of (de Paula et al., 2019), significantly contributes to the body of knowledge related to DT by (i) offering the first attempt to identify CSFs for DT implementation and (ii) directing research efforts to further analyse the benefits and barriers of design thinking.

However, to date, there has not been empirical studies that identified critical success factors for a successful DT implementation based on existing research proposed by de Paula et al., (2019). From this study identified 4 key dimensions and 20 critical success factors that can provide both scholars and practitioners with a more holistic view of DT success. This study was only the first step towards understanding what critical factors play a role when implementing DT. As future work, the next step of this research is to validate the list with the industry.

Considering this, the aim of this paper is to identify the critical factors (success and impeding factors) of Design Thinking implementation in prototypes design experiences of SMEs clusters in less developed countries.

Factors supporting or impeding design thinking implementation were categorized under the theme's "success" factors and "impeding" factors.

The literature review of critical success factors proposed by de Paula et al., (2019) is shown in Table 1.

Table 1. Overview of the identified critical success factors.

Dimensions	Factors	Source
Strategy	Secure management support	Carlgren et al. (2016), Holloway (2009), Rosensweig (2011), Hassi & Laakso (2011)
	Having fundamental guidelines for design thinking	Rosensweig (2011), Kimbell (2009), Hassi & Laakso (2011)
	Ensure fundings for design thinking initiatives	Carlgren et al. (2016), Brown (2008)
	Having clear metrics	Carlgren, Rauth, et al. (2016), Liedtka (2011)
Culture	Diversity orientation	Holloway (2009), Rosensweig (2011), Hassi & Laakso (2011)
	Foster empathy	Brown (2008), Kimbell (2009), Liedtka (2011), Lockwood (2009)
	Ability to handle ambiguitious situations	Dunne et al. (2006), Gloppen (2009), Sato et al. (2010)
	Ability to handle complexity and uncertainty	Liedtka (2011), Boland & Collopy (2004), Cooper et al. (2009), Dew (2007)
	Establish collaboration and cross-functional teams	Dunne et al. (2006), Gloppen (2009), Sato et al. (2010)
Implementation	Provide necessary material	Micheli et al. (2012), Carlgren et al. (2014)

	Innovation spaces	Carlgren et al. (2014), Brown (2008)
	Establish flexible and responsive processes	Holloway (2009), Rosensweig (2011), Brenner et al. (2016)
	Integrate DT into NPD and related processes	Micheli et al. (2012), Rosensweig (2011)
	Apply lessons learned from past projects	Wölbling et al. (2012), Carlgren, Elmquist, et al. (2016), Brenner et al. (2016)
	Access to the user	Brown (2008), Holloway (2009), Ward et al. (2009)
Competences	Provide training on DT	Micheli et al. (2012), Carlgren, Elmquist, et al. (2016), Rosensweig (2011)
	Collaborative initiative with key partners	Micheli et al. (2012), Rosensweig (2011)
	Create DT awareness	Dunne et al. (2006), Sato et al. (2010), Carlgren et al. (2014)
	Enable the optimal team skills	Carlgren, Elmquist, et al. (2016), Brown (2008), Seidel & Fixson (2013)
	Include DT principles into everyday work	Carlgren, Elmquist, et al. (2016), Brown (2008), Liedtka (2011)

Source: de Paula et al. (2019)

By reflecting on the identified CSF, it is possible to notice that the success factors identified have the potential to support some of the DT principles and/or address pressing challenges.

According to Carlgren et al., (2016b) design thinking principles are: (P1) user focus, (P2) problem framing, (P3) visualization, (P4) experimentation and (P5) diversity. The challenges of implementing DT are (C1) misfit with existing processes and structures, (C2) resulting ideas and concepts are difficult to implement, (C3) value of DT is difficult to prove, (C4) DT principles/mindsets clash with organizational culture, (C5) existing power dynamics are threatened, (C6) skills are hard to acquire and (C7) communication style is different.

3. Methodology

The participatory action research (PAR) methodology was applied by the active participation of researchers and participants (in this case managers, university researchers and students) in the construction of collaboratively generate knowledge (i.e., as a participatory process) (Lake and Wendland, 2018). PAR is viewed as opportunity for constructing new knowledge and developing new ways of integrating theory, practice, and people's everyday experiences.

(McIntyre, 2008) explains that the PAR approach is characterized by:

• the active participation of researchers and participants (in this case, socio-productive actors like SMEs managers and students) in the construction of knowledge.

• the promotion of self- and critical awareness leading to individual, collective, and/or social change.

• emphasis on a co-learning process whereby researchers and users plan, implement, and establish a process for disseminating information gathered by the research project.

A qualitative methodological approach of five case studies (Yin, 2018) focusing on projects developed with SMEs in Bolivia was used. Data collection was carried out through interviews (Brinkmann and Kvale, 2015; Sampieri, 2014) that were applied to SMEs managers/representative. Informed consent was obtained in verbally form during the initial meeting with the owner or representative of the SME. During this meeting, the research scope was presented and explained. The interviews for the case studies were conducted digitally by videoconference using Zoom, from October to November of 2022, with durations ranging from a minimum of 25 minutes to a maximum of 45 minutes approximately.

The data analysis was based on qualitative studies that generate new explanations and theories about the phenomenon (Cabrera and González, 2019) regarding the challenges and benefits of DT based on identified critical factors of Design Thinking implementation.

3.1. Case selection and data collection

The selection process for conducting the five case studies has been established as follows:

a. Have been involved in Cluster initiatives at the Unit of Technology Transfer at Universidad Mayor de San Simon.
b. Availability of data and following process at the Unit of Technology Transfer at UMSS in the context of cluster initiatives.
c. To have participated in the design process of the prototype during the year 2022.

Based on those criteria, we have identified five projects of SMES in Bolivia for case studies (Refer to Table 2), three of them belonging to the Food Cluster Cochabamba and the other two to the Green Technology Cluster.

Table 2. Interview list of 5 case studies

Case Study	Interviewees	Cluster
Sesame extruder	Manager 1	Food Cluster
Hammer Mill	Manager 2	Food Cluster
Wheatgrass extruder	Manager 3	Food Cluster
Dutch Pile	Manager 4	Green Technology Cluster
Mixer	Manager 5	Green Technology Cluster

Source: Authors' own creation

An interview guide, presented in Appendix 1, was organized in 3 main stages: the introduction, the design thinking processes, and the final reflections.

In the first introductory section, the interviewer provided guidance on the scope and objectives of the interview, as well as asked introductory questions to learn about the interviewee's personal and professional experience. The second section, which consists of

DT processes, is a recapitulation of the interviewee´s experience in the design of the prototype. And the third one consists of the final reflections, where they were asked for some recommendations for improvement.

4. Results

The result section is divided into two parts: introduction of case studies and critical factors of Design Thinking. First Table 3 shows a brief introduction of case studies with respective details of the followed process for design of prototypes, the structure followed is based on the Design Thinking phases.

The case of *sesame extruder* consists of design of a machine prototype for the extrusion of sesame paste, this was a successful experience because the entrepreneur could get the proposal of the design of a functional prototype after various iterations developed to improve the cost of the scalable extrusion prototype. One key aspect was the proactive profile and honest work of students called novice designers who participated in this project.

"There was transparency regarding quotations to lower the final cost of the prototype". (Manager 1)

Additionally, the open-minded manager of this company allows to explore multiple ways to solve problems and discover the option that best delivers competitive advantage (Clark and Smith, 2010) based on the variety of proposed solutions by students.

"The brainstorming of technical aspects allowed me to learn many important things about the concept of the machine". (Manager 1)

The manager of case of *hammer mill* for garlic and onion grinding prototype looks to get this prototype to automatize the spice product line because of the demand increasing for these products. This prototype exceeds the budget because of unstable balance between design with commercial considerations (Ferrara & Lecce, 2020).

"The productive capacity of the machine turned out to be a difficulty due to the issue of increased cost and lack of financial resources." (Manager 2).

Despite this, the project was successful after lot of iterations to get a functional prototype.

"It was a good experience to receive feedback from the engineers at the research center to define the concept of the machine that allows grinding a variety of spices with a specific productive capacity". "Mutual feedback (manager, researchers and student), constant learning." (Manager 2).

The case study of design of *wheat grass milling* was a failure experience because of the inconsistent participation of the student.

"More fluid communication with the student and the teacher in charge". (Manager 3)

As a result of these obstacles the length of time of prototype and testing phases increases a lot, and the consequences are the negative perception of the manager regarding the design project.

"A lot of time was wasted in defining a final design that did not exceed the initial proposed budget". (Manager 3)

The case of design of *Dutch pile* prototype was successful besides the long length of time of the project.

"Communication between the academic and administrative part of the university and the company must be improved". (Manager 4)

Author

This experience could get a functional prototype because of many iterations realized specially in the phases of define, ideate, prototype and test. Early communication on how to convert new design ideas into commercial realities was important, achieved through a shared understanding of manufacturing processes, with key consideration given to time, cost and feasibility (Paay, 2021).

"The willingness to help in the design of the machine" (Manager 4).

The last case consists of design of a ***mixer*** prototype, as an agitator that supports a high density, for the cleaning products offered by the company. This case was not so successful because of the inconsistent participation of the students with the proposal for the design.

"The functions of the agitator were expanded so that it can be used for various raw materials according to the company's requirements". (Manager 5)

"Time wasted in defining a final design that did not exceed the initial proposed budget" (Manager 5).

Table 3. Introduction of case studies with respective details of design process of prototypes.

Case Study	Sesame Extruder	Hammer Mill	Wheatgrass extruder	Dutch Pile	Mixer
Design brief	Design a customized machine prototype for the extrusion of sesame paste.	Design of a hammer mill prototype for garlic and onion grinding.	Design of a prototype for wheat grass milling.	The preparation of the pulp takes a long time, so it is necessary to make a prototype of a Dutch Pile.	Design of an agitator that supports a high density, for the cleaning products offered by the company, which contain corrosive compounds.
Project duration and specifics	Four months duration. Two students of the mechanic area designed the virtual prototype and 3D printed prototype.	Four months duration. Two students of mechanic and electromechanics area designed the virtual prototype.	Five months duration One student of electromechanics area realized the virtual prototype.	Six months duration. One student of the mechanic area designed and did simulation of virtual prototype.	Six months duration. One student of electromechanics area designed the virtual prototype.
Activities realized in design process. **1.Emphatize:**	Presentation meeting of all stakeholders (entrepreneur, cluster team and students).	Presentation meeting of all stakeholders	Presentation meeting of all stakeholders	Presentation meeting online of all stakeholders because of the location in other city of the enterprise.	Presentation meeting of all stakeholders.
2. Define:	Internalization of the requirements and capabilities of the machine being sought, feedback was obtained from the design team regarding the functionality of the machine.	A sketch of the prototype and the functions of the machine was developed.	A broken extruder was brought in to replicate the model.	The various models of Dutch piles were evaluated to see which one best suits the company's production capacity.	It took a long time to develop the concept due to lack of data collection (density, viscosity, speed, quantity) to better propose the design of the movable agitator.
3. Ideate:	Brainstorming of technical aspects to define the machine concept.	Definition of technical specifications of the machine.	Brainstorming of functional and technical aspects to define the machine concept.	Brainstorming of technical aspects to define the machine concept.	The functions of the agitator are extended so that it can be used for various raw materials.
4. Prototype:	A prototype of the most critical mechanisms is made on a small scale with a 3D printer.	A virtual prototype is designed in SolidWorks software.	A virtual prototype and a fluid simulation is realized in SolidWorks software.	A virtual prototype and a motion simulation is realized in SolidWorks software.	A virtual prototype is designed in SolidWorks software.
5. Test:	The test of function and composition of the prototype was successful, due to the various iterations performed and the 3D printing of the most critical components. However, the cost testing of the physical prototype increased due to the stainless-steel material. This was the tipping point that slowed down the design proposal time.	The functional and compositional testing of the virtual prototype was successful, despite the high final budget proposal due to the stainless-steel material.	The performance simulation of the virtual prototype had some shortcomings. Likewise, three cost proposals were made with different materials in order not to exceed the company's budget limit.	The test of function and composition of the virtual prototype of the Dutch pile was successful. Even though the cost proposal exceeded the initial budget of the entrepreneur.	The tests of the virtual prototype have some shortcomings. Iterations are still in progress to obtain the cost proposal for the physical prototype.

Source: Authors' own creation

In general Table 3 shows that three out of 5 (60 %) of the case studies are successful because after some iterations and continuous feedback could get a functional design prototype that answers the requirements of the managers. These cases thought that Design Thinking processes followed as a strategy of design of prototypes helped them to follow the process and participate in each phase to get better results. The other two (40%) failed because there exists some inconsistent participation of students that oversaw the design of the prototype. As a result, these two cases have some difficulties following the DT processes.

In general, all the cases coincided that the most critical processes of DT were prototype and test because of the necessity to do a lot of simulations of functionality and composition to answer the technical requirements.

Second, a double-entry matrix with the results obtained of critical factors of Design Thinking. According to Miles et al., (2020), a matrix is a tabular format that collects and organizes data for easy visualization and detailed analysis. Thus, a double-entry matrix was constructed where the Design Thinking success and impeding factors, on the one hand, and Dimensions of Design Thinking, on the other hand, are visualized. Each one with its respective codification and nomination.

Thus, the matrix presented in Table 4 crosses coding themes and sub-themes. A clear example would be the Success Factors (SF) which is the theme, and its sub-theme would be the foster empathy, thus making visible the coding cycles that were performed to identify these patterns of factors that influence in the dimensions of DT implementation.

On the entrepreneurial perspective side, Table 4 shows critical factors of Design Thinking implementation identified by SMEs managers. According to managers the most outstanding success factors are *fostering empathy*, *establishing collaboration* and *cross-functional teams*, *experimentation and iteration*, and *collaborative initiative with key partners*. Additionally, managers mentioned less frequently these other success factors: ability to handle ambiguous situations, and ability to handle complexity and uncertainty. Regarding the most prominent impeding factors highlights *insecure management support*, *time constraints* and *resource constraints*. Also recognized other impeding factors that are less mentioned like: communication style is different, far innovation spaces, inconsistent participation and not provide necessary material.

Regarding the other critical factors proposed by (de Paula et al., 2019) that don't appear in each dimension of Table 4 is because managers don't mention nothing related to these missing factors of Table 1.

Table 4. Critical factors of Design Thinking implementation identified by SMEs Managers of cluster scenario in Design Prototypes.

Dimensions	**Design Thinking Factors**	
	Success Factors **(SF)**	Impeding Factors **(IF)**
Strategy		*** Insecure management support**
Culture	*** Foster empathy** * Ability to handle ambiguous situations * Ability to handle complexity and uncertainty *** Establish collaboration and cross-functional teams**	*Communication style is different
Implementation	*** Experimentation and iterations**	* Far Innovation spaces *** Time constraints** * Inconsistent participation * Not provide necessary material *** Lack of dedicated resources (Resource constraints)**
Competences	*** Collaborative initiative with key partners**	

Source: Authors' own creation

Note. The most frequently identified critical factors are those highlighted and in bold type.

The following Table 5 are segments of the SMEs managers´ responses that represent the most outstanding *Success Factors*: foster empathy, establish collaboration and cross functional teams, experimentation and iterations and collaborative initiative with key partners.

Table 5. Quotes of responses of SMEs managers of Success factors identified.

Success Factors	**Quotes**
Foster empathy	*"There was transparency regarding quotations to lower the final cost of the prototype". (Manager 1)*
	"It was a good experience to receive feedback from the engineers at the research center to define the concept of the machine that allows grinding a variety of spices with a specific productive capacity". (Manager 2)
	"The functions of the agitator were expanded so that it can be used for various raw materials according to the company's requirements". (Manager 5)
Establish collaboration and cross-functional teams	*"The willingness to help in the design of the machine" (Manager 4).*
	"The cluster spaces give us the opportunity to create strategic alliances with research centers" (Manager 5)
	"The experience of the university's engineers allowed them to contribute to the development of machine prototype designs that support small

	businesses so that they no longer have the need to import machines". (Manager 2)
Experimentation and iteration	*"The brainstorming of technical aspects allowed me to learn many important things about the concept of the machine". (Manager 1)*
	"Mutual feedback (manager, researchers and student), constant learning." (Manager 2)
Collaborative support from key partner	*"Being part of the cluster opens doors for other services like the facilitation on food safety and trade issues, with other research centers of the university". (Manager 1)*
	"Being part of the cluster allows you to expand your network of contacts with the UMSS research centers that support companies". (Manager 2)

Source: Authors' own creation based on responses of interviews

The first one is **foster empathy** that is part of the culture of Design Thinking. It has been argued that to perform DT-related activities it is necessary to foster a culture that promotes empathy towards the user and co-workers, to comprehend the situations and perspectives of others, both imaginatively and affectively (Köppen and Meinel, 2014). This factor runs a crucial role in effective co-creation and co-design (Bharti et al., 2014; Jagtap, 2022). The empathy allows researchers think as SMEs managers in all the phases of DT (*empathize, ideate, define, prototype and test*) to obtain a design that answers all the requirements of the final user, considering aspects of cost, composition and functionality with the correct mechanism and productive capacity.

"There was transparency regarding quotations to lower the final cost of prototype". (Manager 1)

The second, **establish collaboration and cross-functional teams** that is part of the culture of DT. The focus on collaboration through cross-functional teams associated with DT is seen as enhancing collective creative problem solving by bringing to conversations diverse points of view (Carlgren et al., 2016b). By using interdisciplinary teams, DT incorporates diversity and leverages different paradigms and tool sets from each profession to analyse, synthesize, and generate insights and new ideas.

"The cluster spaces give us the opportunity to create strategic alliances with research centers". (Manager 5)

The third that is part of implementation of DT, refers to **Experimentation and Iteration** by encouraging the participation of people in the whole project (Jagtap, 2020). The factors of establish collaboration and cross-functional teams, and experimentation and iteration are identified in the four phases of define, ideate, prototype and test because to obtain an effective prototype is necessary to have a lot of iterations before the development of the official machine.

"The brainstorming of technical aspects allowed me to learn many important things about the concept of the machine". (Manager 1)

Finally, the fourth about securing **collaborative support from key partners** can be a way to improve employees' design thinking competence (Rosensweig, 2011). In this way, SMEs enterprises could promote projects in partnership with universities and/or research institutes (de Paula et al., 2019) and this is the case of these university-industry collaboration 'Cluster' spaces. This factor is identified in the phases of empathy and define because the managers identified at university as a partner that supports them in the proposal of a design project for the development of a machine. In this partnership university brings

SMEs some financial benefits regarding laboratories analysis. In that sense, design methods support university-industry collaborations to produce both research and commercial outcomes (Paay et al., 2021).

"Being part of the cluster allows you to expand your network of contacts with the UMSS research centers that support companies". (Manager 2)

Below at Table 6 are segments of the SMEs managers´ responses that represent the most prominent *Impeding factors* of Design Thinking implementation: insecure management support, time constraints and resource constraints.

Table 6. Quotes of responses of SMEs managers of Impeding factors identified.

Impeding factors	**Quotes**
Insecure management support	*"More fluid communication with the student and the teacher in charge". (Manager 3)*
	"Inconsistent participation of the design team to all of the meetings". (Manager 1)
	"Commitment between all parties (managers, researchers, students) and seriousness in the execution of the project". (Manager 2)
	"Communication between the academic and administrative part of the university and the company must be improved". (Manager 4)
Time constraints	*"Time wasted in defining a final design that did not exceed the initial proposed budget" (Manager 5)*
	"It is recommended that times be optimized to obtain the machine designs as quickly as possible" (Manager 1)
	"Meet the execution dates of the machine design"(Manager 2)
	"A lot of time was wasted in defining a final design that did not exceed the initial proposed budget". (Manager 3)
Resource constraints	*"The final design budget was excessive and exceeded the initial budget that I had at the beginning. This was the turning point that stopped the development of the machine". (Manager 1)*
	"The productive capacity of the machine turned out to be a difficulty due to the issue of increased cost and lack of financial resources." (Manager 2)

Source: Authors' own creation based on responses of interviews

The first is **Insecure management support** recognized in the dimension of strategy of DT. Design Thinking have been promoted as holistic approaches to management. In earlier work (Carlgren et al., 2016b), argued for a shift from a process view of DT, to seeing DT as a management concept that needs to be understood both as an idea and its enactment in organizations through the practice of individuals and teams. In these experiences managers identify this factor in fourth phases of DT like ideate, define, prototype and test because they noticed that there is a lack of compromise and consequently non-fluent communication among all stakeholders that prevents the project from being developed more effectively.

"Communication between the academic and administrative part of the university and the company must be improved". (Manager 4)

The second **time constraints** are in dimension of implementation of Design Thinking. This impeding factor limits the exploration of concepts and restricts the development of a shared understanding from discussions in participatory activities with people (Galafassi et al., 2018; Sushama P et al., 2018). This factor is identified in the first phases of empathizing, ideate, and define because from the beginning there is an inconsistency in the times that managers projects versus the time that the academic sector projects.

"Time wasted in defining a final design that did not exceed the initial proposed budget". (Manager 5)

Finally, **resource constraints** are highlighted in implementation dimension of DT, this factor lead to interruptions in projects, with negative consequences for the coherence and effectiveness of co-design sessions (Jagtap, 2020). This factor is identified in the last phases of prototype and test because managers noticed that the budget of the final project exceeds the initial budget that they proposed since the beginning of the project. This happens because they compare machines developed in countries that have mass production and don't consider the additional import costs.

"The final design budget was excessive and exceeded the initial budget that I had at the beginning". (Manager 1)

At the end of this analysis, the importance of multi-step data processing approach was understood, because it helps to visualize the patterns and the overall picture of the database obtained.

5. Discussion

The critical factors (success and impeding factors) of Design Thinking implementation identified by SMEs managers of these university cluster initiatives show the entrepreneurial perception inside these university-industry collaboration spaces. It is highlighted that the most outstanding success factors identified like foster empathy, establish collaboration and cross-functional team, experimentation and iteration and collaborative initiative with key partners, are part of the Design Thinking method itself.

This implies that SMEs managers were able to follow and understand the Design Thinking processes by being part of collaborative meetings. These interactive meetings, both face-to-face and virtual, facilitated the identification of these factors.

These actions managed by UTT, by following a Developmental university approach, encourage the socially valuable use of knowledge to cooperate with a wide variety of actors in interactive learning processes(Arocena et al., 2017), which results in generating collaborative spaces and empathy with all stakeholders. This is aimed at improving capacities to produce goods and services as well as to solve problems, giving priority to the needs of the most disadvantaged sectors such as SMEs in developing countries like Bolivia.

The successful case studies like Sesame extruder, Hammer mill and Dutch pile are characterized because of the collaborative work among researchers, novice designers, managers and facilitators and the resilience and open minded of SMEs' managers to explore the best option of the prototype concept which gives a good solution.

On the other hand, the impeding factors identified like insecure management support, time constraints and resource constraints are the results of some problems identified in the context of limited resources enterprises in countries with low-middle income economies like Bolivia.

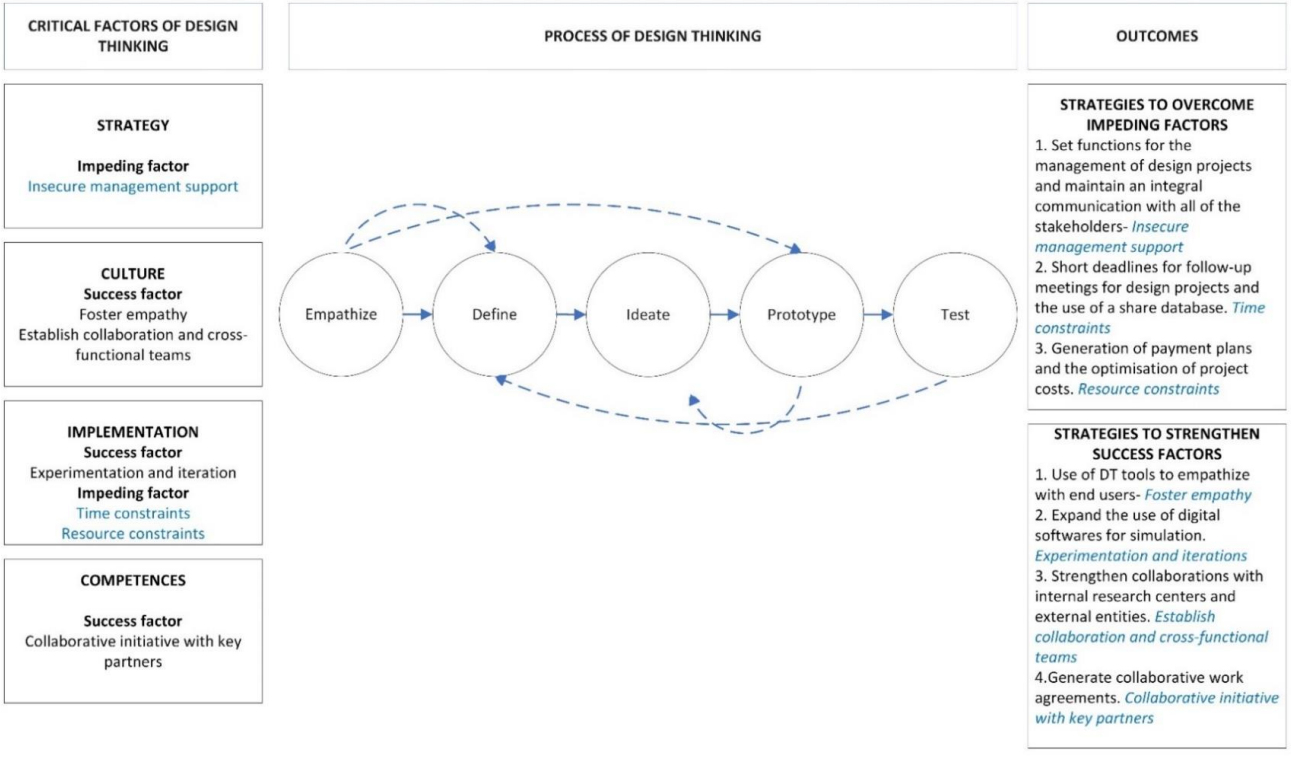
Resource constraints pose significant challenges to the development of new technology of prototype machine, particularly within the context of university-industry collaboration spaces. Universities are compelled to devise strategies to enhance the design and development of prototypes with minimal resource utilization, due to the limited budgets available to the managers of small and medium-sized enterprises (SMEs).

At the same time the impeding factor of insecure management support is a result of the lack of trust and fluid communication that exists among all the stakeholders. This is an aspect of a culture with limited resources in which people don't trust each other, especially in aspects that imply money and business. Because of this the innovation could be affected because of the lack of ongoing communication between the producers and users of knowledge, which is an invariably feature characterizes successful innovation (Sarewitz and Pielke, 2007). The case studies of wheat grass milling and mixer prototypes were not particularly successful, primarily due to insufficient communication between students and SME managers. This issue was attributed to the inconsistent participation of students, who exhibited a non-proactive approach. Consequently, the time required to finalize the design proposals was significantly extended.

After these brief results, Figure 2 shows a holistic scheme with the most important critical factors of design thinking identified by managers in the four dimensions, and the strategies proposed from entrepreneurial perspective to improve these critical factors.

These strategies based on the critical factors identified can improve the DT processes for the design of prototypes for SMEs in cluster initiatives. More details of each strategy will be shown in the following discussion.

Figure 2. Design thinking framework of critical factors in university-industry collaboration spaces. **Source:** Authors' own creation.



Since DT challenges not only organization of work but also power structures, managers that want to truly engage in DT need to firmly communicate their support and encourage their employees to engage in its implementation (Carlgren et al., 2016b). In this way, the need to improve the link between DT and **strategy** is highlighted by recent research. In that sense, the perspective of SMEs managers agrees that ***ensuring management support*** is the critical factor that needs to be improved in the first instance to have the necessary resources to perform DT-related activities (Carlgren et al., 2016b). According to SMEs managers, one aspect that could influence is the communication style which is different when they must define the concept of the prototype.

Prior research has shown that several firms pointed out that there is a communication barrier that needs to be overcome, related to the fundamental principles/mindsets of DT (Carlgren et al., 2016a). This lack of fluid communication and trust are some aspects that affects the societies with limited resources and implies a challenge to look solutions to overcome this situation. Additionally, researchers recognized the organization of the design team to develop a good project depends on secure management support that facilitates creating a commitment to co-design in organisations and among individuals (Pirinen, 2016). A strategy suggested by SMEs managers based on these experiences and could influence in the secure management support is that design team must set functions for the management of design projects and to maintain an integral communication with all the stakeholders to get successful projects.

Under the dimension **culture**, we summarized CSFs that are necessary to foster a DT culture inside cluster initiatives. The success factor recognized by all SMEs managers are ***foster empathy*** and ***establish collaboration and cross-functional team***. This is attributed to the fact that designers from university begin to assume the perspective of the client or user, thus appealing to empathy to better recognize and address the human and often tacit needs of users-clients (Nakata, 2020). It also involves probing the lived experiences, thoughts, feelings, and meanings that people attribute to what they do or have (Carlgren et al., 2014). In this sense, the case studies of the sesame extruder and the hammer mill showed in more detail their experience and the feelings that led them to search for the prototype that would allow them to improve the economic returns of both their company and their local suppliers. The latter refers to the case of the hammer mill that seeks to help rural communities that supply the company with vegetables and spices, which will contribute to increase their production and scale up nationally. A strategy suggested that could strengthen this success factor and structure the data is the use of DT tools to empathize with end users.

Collaboration and team diversity is a critical factor that fosters a DT culture and supported the use of design thinking tools (Elsbach and Stigliani, 2018). Cluster initiatives work with interdisciplinary teams for the development of local technology to respond SMEs needs through prototypes. A collaborative work style is seen as important in tackling complex and "wicked" problems through gaining knowledge from many fields and different disciplines (Micheli et al., 2019), promoting diverse perspectives from within and outside the organization (Carlgren et al., 2016b) and merging them in a meaningful and novel way. By using interdisciplinary teams, DT incorporates diversity and leverages different paradigms and tool sets from each profession to analyse, synthesize, and generate insights and new ideas (de Paula et al., 2019). At the end, the 5 cases highlighted the factor of establishing collaboration and cross-functional team because of the collaborative space which creates a trust environment. Trust helps overcome interpersonal and organizational barriers, reduces opportunistic behaviours, and makes participants more willing to share

resources, and personal relationships help build social capital (Steinmo and Rasmussen, 2018). In that sense, a strategy to maintain this success factor is to strengthen collaborations with internal research centres and external entities. By this way, the capabilities of innovation that SMEs clusters need to have consist of interacting with other stakeholders and solving problems for development of prototypes under conditions of scarcity (Srinivas and Sutz, 2008) given the context of SMEs in Bolivia.

The dimension of **Implementation** combines CSFs that support employees when implementing design thinking. The perception of both actors recognized ***experimentation and iteration*** as the most important critical success factor. Cultural elements of DT, such as the focus on experimentation refers to iteratively developing and testing ideas in ways that are convergent and divergent, working on multiple solutions to maximize the creative value of process and outcome (Gheerawo, 2018).

These dimensions are described as central to DT (Carlgren et al., 2016b). According to (Deininger et al., 2017) the proposed 'quick and dirty' prototyping approach supports a greater number of iterations and enables designers to select the best solution to a design challenge without large amounts of 'sunk cost,' i.e., time and money, invested. In that sense, the predisposition of the designers to be able to have a lot of iterations to create the concept and design of prototype, carry out the development of the prototype. Additionally, the participation of SMEs managers in projects allowed shaping the design work influences their willingness to participate in future projects (Pap et al., 2019). A strategy of expanding the use of digital software's for simulation helps to broaden the use of different programs for analysing more aspects of the prototype to secure the total functionality.

Regarding the impeding factors, ***time constraints*** are recognized by SMEs managers and researchers because of the long time it takes for the student to formally start his or her internship in the company. This factor limits exploration of concepts and restrict the development of shared understanding from discussions in participatory activities with people (Galafassi et al., 2018; Sushama P et al., 2018) this results in the lack of efficiency of information processing. Some strategies suggested to process more quickly the information are short deadlines for follow-up meetings for design projects and the use of a share database.

Additionally, all SMEs managers recognized ***resource constraints*** as the most critical impeding factor because managers without financial resources can-not make an investment for the acquisition of a scalable physic prototype, so they must look for banking institutions that can finance their investment. The fact is one of the biggest problems of SMEs is the difficulty to access financing (Flores, 2018). This is due to the high costs of financing, bank requirements and insufficient company guarantees (Silvestre, 2015). Given the limited resources available to SMEs, one strategy for the university to continue with the manufacture of these prototype projects is the generation of payment plans and the optimisation of project costs to make the project accessible to SMEs.

Lessons learnt of previous design projects promote the searching for strategies to develop prototypes under scarcity conditions making use of a restricted mix of resources to get satisfactory solutions for users (Arocena et al., 2017).

The dimension of **competence** shows that is fundamental to promote awareness of DT implementation among all functions in the clusters. Securing ***collaborative support from key partners*** can be a way to improve employees' design thinking competence (Rosensweig, 2011). In this way, SMEs enterprises could promote projects in partnership with universities and/or research institutes (de Paula et al., 2019) and this is the case of these university-industry collaboration 'Cluster' spaces. The strategy for generating

collaborative work agreements could secure and formalize the collaborative initiative with key partners.

6. Conclusions

This study looks to identify critical factors of Design Thinking implementation and how can be improved them based on the experience of 5 cases of prototypes designed for small and medium sized enterprises of clusters. This first empirical study of design thinking implementation analysed from the success and impeding factors is crucial to determine the critical success factors that allows a good implementation of design thinking method for the design of prototypes in university- industry collaboration spaces like SMEs clusters.

Thus, in this empirical study we were able to identify the presence of four success factors which are: fostering empathy and establishing collaborative and cross-functional teams, these two factors are recognized in the culture dimension of design thinking. The factor of experimentation and iterations as part of the implementation dimension and finally the factor of collaborative initiative with key partners as part of the competences. Thus, three impeding factors were also identified, which are: insecure management support within the strategy dimension, time limitations and resource limitations in the design thinking implementation dimension. These three factors are context dependent of societies with limited resources like SMEs enterprises of a country with lower-middle-income economies like Bolivia.

The strategies identified to improve the DT processes based on these critical factors identified in these design experiences of SMEs cluster initiatives are set functions for the management of design projects to maintain an integral communication, short deadlines for follow-up meetings for design projects, flexible payment plans and the optimisation of project costs to make the project accessible to SMEs. The implications of these strategies allow to get an efficient prototype using restricted resources to get solutions for deprived actors like SMEs of Bolivia, who must participate in the whole interactive processes to promote inclusive innovation in the context of cluster initiatives.

Additionally, the strategies to strengthen the successful factors are the use of DT tools to empathize with end users, the use of digital software's to improve simulations, strengthen collaborations with internal research centers and external entities and generating collaborative work agreements. The methodology 'Participatory action research' used for development of prototypes in Cluster initiatives promotes the integration of theory and practice approaches for the construction of knowledge which facilitates the application of these strategies.

These findings are a starting point of a range of opportunities on the improvements that need to be made within the context of cluster spaces to respond effectively to the design of prototypes for SMEs enterprises.

Author

7. Further Research

The key contribution of this research is to have an initial list of Critical factors identified based on what researchers have found to be core elements to the design thinking implementation in the context of a university-industry collaboration space. The study revealed that one of the most important topics of discussion among SMEs managers and researchers of university is the secure management support to successfully implement DT in cluster initiatives. From this empirical analysis, we identified 4 critical success factors and 3 impeding factors that can provide managers with a more holistic view of DT success and improvement. This empirical study will open future research to find other critical factors for the implementation of Design Thinking in similar contexts of university-industry collaboration spaces.

References

Acevedo, C., Cespedes, W.M.H., Zambrana, J.E., 2015. "Developmental University" approaches in developing countries: Case of the Universidad Mayor de San Simon, Bolivia., in: Developing Inclusive Innovation Processes and Co-Evolutionary Approaches in Bolivia. Blekinge Institute of Technology, Sweden, pp. 53–72.

Antoljak, V., Kosović, M., 2018. Design thinking za nedizajnere – kako riješiti poslovne probleme i uspješno inovirati. Zagreb: Školska knjiga. (in Croatian).

Arandia, J.P., Arevalo, J., Acevedo, C., 2020. Estudio de los procesos de facilitación para el Desarrollo de Prototipos de Máquinas con MyPEs del Cluster de Alimentos Cochabamba 1–132.

Arandia, J.P., Olivares, J., 2020. Criterios de Buenas Practicas de Facilitacion para procesos de prototipaje en paises en desarrollo: Caso Cluster de Alimentos Cochabamba. DDigital - UMSS.

Arocena, R., Göransson, B., Sutz, J., 2017. Developmental universities in inclusive innovation systems: Alternatives for knowledge democratization in the Global South, Developmental Universities in Inclusive Innovation Systems: Alternatives for Knowledge Democratization in the Global South. https://doi.org/10.1007/978-3-319-64152-2

Bello Pintado, A., Kaufmann, R., Merino Diaz-de-Cerio, J., 2015. Advanced manufacturing technologies, quality management practices, and manufacturing performance in the southern cone of Latin America. Management Research 13, 187–210. https://doi.org/10.1108/MRJIAM-03-2015-0580

Ben Mahmoud-Jouini, S., Midler, C., Silberzahn, P., 2016. Contributions of Design Thinking to Project Management in an Innovation Context. Project Management Journal 47, 144–156. https://doi.org/10.1002/PMJ.21577

Best, K., 2006. Design Management: Managing Design Strategy. Process and Implementation, AVA publishing.

Bharti, K., Agrawal, R., Sharma, V., 2014. What drives the customer of world's largest market to participate in value co-creation? Mark Intell Plan 32, 413–435. https://doi.org/10.1108/MIP-07-2013-0111

Brinkmann, S., Kvale, S., 2015. Interviews: Learning the craft of qualitative research interviewing. Sage Thousand Oaks, CA.

Brown, T.,, Katz, B., 2011. Change by design. . Journal of product innovation management 28, 381–383.

Brundenius, C., Lundvall, B.-Å.,, Sutz, J., 2009. The role of universities in Innovation systems in developing countries: Developmental university systems – Empirical, analytical and normative perspectives, in: In B. Lundvall, K. J. Joseph, C. Chaminade, & J. Vang (Eds.), Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting. Cheltenham, UK and Northampton, MA, USA: Edward Elgar Publishing Limited., pp. 311–333.

Buhl, A., Schmidt-Keilich, M., Muster, V., Blazejewski, S., Schrader, U., Harrach, C., Schäfer, M., Süßbauer, E., 2019. Design thinking for sustainability: Why and how design thinking can foster sustainability-oriented innovation development. J Clean Prod 231, 1248–1257. https://doi.org/10.1016/j.jclepro.2019.05.259

Cabrera, R., González, D., 2019. Influences of technological attributes on sourcing of manufacturing technologies in developing countries: The case of Peru. Management Research 17, 359–378. https://doi.org/10.1108/MRJIAM-10-2018-0872

Cagnin, C., 2018. Developing a transformative business strategy through the combination of design thinking and futures literacy. Technol Anal Strateg Manag 30, 524–539. https://doi.org/10.1080/09537325.2017.1340638

Camburn, B.A., Dunlap, B.U., Linsey, J.S., Crawford, R.H., Wood, K.L., 2013. Methods for Prototyping strategies in Conceptual Phases of Design 1–10. https://doi.org/https://doi.org/10.1115/DETC2013-13072

Carlgren, L., Elmquist, M., Rauth, I., 2016a. The Challenges of Using Design Thinking in Industry – Experiences from Five Large Firms. Creativity and Innovation Management 25, 344–362. https://doi.org/10.1111/caim.12176

Carlgren, L., Elmquist, M., Rauth, I., 2014. Design Thinking: Exploring Values and Effects from an Innovation Capability Perspective. The Design Journal 17, 403–423. https://doi.org/10.2752/175630614X13982745783000

Carlgren, L., Rauth, I., Elmquist, M., 2016b. Framing Design Thinking: The Concept in Idea and Enactment. Creativity and Innovation Management 25, 38–57. https://doi.org/10.1111/caim.12153

de Paula, D., Dobrigkeit, F., Cormican, K., 2019. Doing it right - Critical success factors for design thinking implementation, in: Proceedings of the International Conference on Engineering Design, ICED. Cambridge University Press, pp. 3851–3860. https://doi.org/10.1017/dsi.2019.392

Deininger, M., Daly, S.R., Sienko, K.H., Lee, J.C., Street, H., 2017. Novice designers' use of prototypes in engineering design. Des Stud 51, 25–65. https://doi.org/10.1016/j.destud.2017.04.002

Dias Daniel, A., 2016. Fostering an entrepreneurial mindset by using a design thinking approach in entrepreneurship education. Industry and Higher Education 30, 215–223. https://doi.org/10.1177/0950422216653195

Elsbach, K.D., Stigliani, I., 2018. Design Thinking and Organizational Culture: A Review and Framework for Future Research. J Manage 44, 2274–2306. https://doi.org/10.1177/0149206317744252

Elverum, C.W., Welo, T., Steinert, M., 2014. The Fuzzy Front End: Concept Development in the Automotive Industry, in: Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference. p. 9. https://doi.org/10.1115/detc2014-35138

Eybers, S. and G.A., 2015. "Identifying Critical Success Factors for Business Intelligence Systems," in: The European Conference on Information Systems Management, Academic Conferences International Limited. pp. 77–84.

Flores, J., 2018. La Bolsa Boliviana de Valores como alternativa de financiamiento para las PyMEs de la ciudad de Cochabamba The Bolivian Stock Exchange as a financing alternative for the SMEs in the city of Cochabamba. Revista Perspectivas 71–96.

Galafassi, D., Daw, T.M., Thyresson, M., Rosendo, S., Chaigneau, T., Bandeira, S., Munyi, L., Gabrielsson, I., Brown, K., 2018. Stories in social-ecological knowledge cocreation. Ecology and Society 23. https://doi.org/10.5751/ES-09932-230123

Gheerawo, R., 2018. Design Thinking and Design Doing: Describing a Process of People-Centred Innovation, in: Advanced Sciences and Technologies for Security Applications. Springer, pp. 11–42. https://doi.org/10.1007/978-3-319-78021-4_2

Ibarra, D., Bigdeli, A.Z., Igartua, J.I., Ganzarain, J., 2020. Business model innovation in established SMEs: A configurational approach. Journal of Open Innovation: Technology, Market, and Complexity 6. https://doi.org/10.3390/JOITMC6030076

Jagtap, S., 2022. Codesign in resource-limited societies: theoretical perspectives, inputs, outputs and influencing factors. Res Eng Des 33, 191–211. https://doi.org/10.1007/s00163-022-00384-1

Jagtap, S., 2020. Barriers and Enablers in Co-designing with Marginalised People, in: Proceedings of the Design Society: DESIGN Conference. Cambridge University Press, pp. 1931–1940. https://doi.org/10.1017/dsd.2020.56

Kelley, T., Kelley, D., 2013. Creative confidence: Unleashing the creative potential within us all. Currency.

Kelley, T., Littman, J., 2006. The Ten Faces of Innovation IDEO's Strategies for Defeating the Devil's Advocate and Driving Creativity Throughout Your Organization.

Knight, E., Daymond, J., Paroutis, S., 2020. Design-Led Strategy: How To Bring Design Thinking into the Art of Strategic Management. Calif Manage Rev 62, 30–52. https://doi.org/10.1177/0008125619897594

Köppen, E.,, Meinel, C., 2014. Empathy via design thinking: creation of sense and knowledge., in: Design Thinking Research: Building Innovators . Springer

International Publishing., pp. 15–28. https://doi.org/https://doi.org/10.1007/978-3-319-06823-7_2

Lake, D., Wendland, J., 2018. Practical, Epistemological, and Ethical Challenges of Participatory Action Research: A Cross-Disciplinary Review of the Literature. J High Educ Outreach Engagem 22, 11.

Latifi, M.A., Nikou, S., Bouwman, H., 2021. Business model innovation and firm performance: Exploring causal mechanisms in SMEs. Technovation 107. https://doi.org/10.1016/j.technovation.2021.102274

Lauff, C.A., Kotys-Schwartz, D., Rentschler, M.E., 2018. What is a prototype? what are the roles of prototypes in companies? Journal of Mechanical Design 140. https://doi.org/10.1115/1.4039340

Li, C., Bacete, G., 2022. Mapping the technology footprint in design for social innovation. International Journal of Innovation Studies 6, 216–227. https://doi.org/10.1016/j.ijis.2022.07.003

Liedtka, J., 2015. Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. Journal of Product Innovation Management. https://doi.org/10.1111/jpim.12163

Lindqvist, G., Ketels, C., Sölvell, örjan, 2003. The Cluster Initiative Greenbook 2.0, Annual Global Conference in Gothenburg.

Malins, J.P., 2011. Innovation by Design: Using Design Thinking to Support SMEs. Porto.

McIntyre, A., 2008. Participatory action research. Los Angeles, London, New Deli and Singapore: Sage Publications. 52.

Micheli, P., Wilner, S.J.S., Bhatti, S.H., Mura, M., Beverland, M.B., 2019. Doing Design Thinking: Conceptual Review, Synthesis, and Research Agenda. Journal of Product Innovation Management 36, 124–148. https://doi.org/10.1111/jpim.12466

Miles, M.B., Huberman, A.M., Saldana, J., 2020. Qualitative Data Analysis: A Methods Sourcebook, SAGE Publication. ed.

Naiman, L., 2019. Design Thinking as a Strategy for Innovation [WWW Document]. The European Business Review. URL https://www.europeanbusinessreview.com/design-thinking-as-a-strategy-for-innovation/ (accessed 5.15.22).

Nakata, C., 2020. Design thinking for innovation: Considering distinctions, fit, and use in firms. Bus Horiz 63, 763–772. https://doi.org/10.1016/j.bushor.2020.07.008

Paay, J., Kuys, B., Taffe, S., 2021. Innovating product design through university-industry collaboration: Codesigning a bushfire rated skylight. Des Stud 76. https://doi.org/10.1016/j.destud.2021.101031

Pap, M., Vdović, R., Baletić, B., 2019. Design Thinking metoda u znanstvenom istraživanju, edukaciji i poslovnoj praksi. Prostor 27, 334–347. https://doi.org/10.31522/P.27.2(58).12

Pirinen, A., 2016. The Barriers and Enablers of Co-design for Services, International Journal of Design.

Rosensweig, R.R., 2011. More than Heroics: Building Design as a Dynamic Capability. Design Management Journal 6, 16–26. https://doi.org/https://doi.org/10.1111/j.1948-7177.2011.00025.x

Sampieri, R., 2014. Metodología de la Investigación, 6 ta Edici. ed, McGraw-Hill/ Interamericana Editores, S.A. DE C.V. México. https://doi.org/10.1192/bjp.111.479.1009-a

Sarewitz, D., Pielke, R.A., 2007. The neglected heart of science policy: reconciling supply of and demand for science. Environ Sci Policy 10, 5–16. https://doi.org/10.1016/J.ENVSCI.2006.10.001

Siang, Y.T., 2020. Design thinking. Interaction Design Foundation. [WWW Document].

Silvestre, E., 2015. El problema del Financiamiento de las PYMES en Bolivia. La Paz.

SITAP-UDAPRO, 2015. Sistema de Información Territorial de Apoyo a la Producción (SITAP-UDAPRO). ATLAS Potencialidades Productivas en Bolivia:Cochabamba potencialidades productivas. La Paz: SITAP-UDAPRO.

Srinivas, S., Sutz, J., 2008. Developing countries and innovation: Searching for a new analytical approach. Technol Soc 30, 129–140. https://doi.org/10.1016/J.TECHSOC.2007.12.003

Steinmo, M., Rasmussen, E., 2018. The interplay of cognitive and relational social capital dimensions in university-industry collaboration: Overcoming the experience barrier. Res Policy 47, 1964–1974. https://doi.org/https://doi.org/10.1016/j.respol.2018.07.004

Sushama P, Ghergu C, Meershoek A, de Witte LP, van Schayck OC, Krumeich A, 2018. Dark clouds in co-creation, and their silver linings: Practical challenges I faced in a participatory project in a resource-constrained community in India, and how I overcame (some of) them. Glob Health Action 11, 142–342. https://doi.org/https://doi.org/10.1080/16549716.2017.1421342

Ulrich, K.T., Eppinger, S.D., Yang, M.C., 2020. Product Design and Development, McGraw-Hill Education. https://doi.org/10.1016/0956-5663(92)90013-D

White, P.J., Kennedy, C., 2022. Designing a module in entrepreneurship for product design students. Industry and Higher Education 36, 217–226. https://doi.org/10.1177/09504222211013742

Yin, R.K., 2018. Case Study Research and Applications. Sage publications.

Paper III

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Journey maps to improve user involvement in innovation processes. Bolivian case of collective greenhouse prototype.

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Abstract

Purpose - This research shows the importance of strengthening user involvement in traditional sectors like agriculture, which constitute a strong pillar for sustainable development. In the case of an agriculture technology like the collective greenhouse prototype, it requires novel methods to involve users during the development phase. Consequently, this article describes and

discusses the application of the journey map developed in collaboration with the agricultural producers responsible for the prototype. The initiative for the greenhouse stems from the need to protect the agroforestry production of pests and the effects of climate change.

Design/methodology/approach – This study utilizes a qualitative methodological approach of single case study regarding the application of one design thinking tool, in the case the journey map, for the development of a collective greenhouse prototype. The prototyping process is facilitated by a public university to support two rural communities.

Findings - The results illustrate how design thinking tools such as journey maps offer the means to explore user experiences, spotting previously unknown needs or problems, generate value propositions with meaning and relevance, and foresee implementation issues not directly related to the technology in focus. Finally, this tool has the potential to facilitate engagement and discussion not only with users, but also with the public at large.

Originality/value – This research distinguishes as a unique exploration of the application of journey maps for increasing user involvement in the innovation process in the rural context of a lower-middle income country like Bolivia. The findings show how journey maps can be used as a design tool for active participation of agricultural producers in technology development.

Research limitations/implications – The implication of this research takes as a base the different types of user involvement to identify the way of user participation in each phase of Design Thinking to improve the development of technology.

Keywords

Design Thinking, journey maps, development of technology, prototype, user involvement.

Introduction and Literature Review

Design practitioners identify that, for the development of innovative-oriented technologies, early involvement of users in technology development can help create more value for the user (e.g., farmer) (Douthwaite et al., 2001; Lindblom et al., 2017). Furthermore, such involvement can also address social problems and foster the development of innovative solutions (Fuad-Luke, 2009; Margolin & Margolin, 2002).

The importance of involving the user in the innovation process lies to increase the communication among all the participants, because some literature of precision agriculture technologies indicate that insufficient communication is a key barrier for innovation to occur (Berthet et al., 2018; Busse et al., 2014). Thus, there is an urgent need for new methods that better integrate and reflect the diversity of actors and technologies involved. Methods derived from design thinking emphasize the importance of empathy with users and their needs, these methods offer a framework not only to understand what users want, but to develop innovations around unique value propositions that create value both for the user and for the stakeholders involved (Moretti et al., 2022). Most design thinking (DT) inspired tools emphasize that the requisites of the users need to better be aligned with the multiple stakeholders involved at the beginning of a development process (Carlgren, Rauth, et al., 2016; Dell'era et al., 2020; Hölzle & Rhinow, 2019). One DT tool that engages with users' requests (Needs and Aims) and visualizes user-centered problems (Pain Points) are journey maps (Carlgren, Rauth, et al., 2016; Richardson, 2010).

Journey maps are visualization tools that provide the means and opportunity to map and understand the multidimensional experiences of a customer when interacting with a company or a product (Lemon & Verhoef, 2016). Journey maps, which are developed in collaboration with users or customers or are undertaken with their particular perspective in mind (i.e., from the perspective of firms), provide a graphical representation of the different stages, interactions, and indeed feelings that mark a user's experience (Actions) when using or purchasing a particular product, and thereby include various points of contact between the user and either the company or a specific product offering (Touch Points) (Calabretta & Gemser, 2015; Howard, 2014).

In this study we analyze the experiences and challenges when using the journey map during three different design phases of a collective greenhouse prototype. The stakeholders in the project are facilitators and researchers, located at a public university, and agricultural producers, in this case identified as users, situated in a rural community in Bolivia.

It is important to characterize the context of these resource-constrained societies of elderly farming families, where agricultural production is the main source of economic income. The need to develop this technological innovation initiative arises from the productive losses of agroforestry crops due to constant climatic changes and pests, which imply a risk for the food supply and economic income of producers of two rural communities. The incidence of the factors that most influence production losses are: 40 % adverse weather conditions and 60 % lack of water (Ricaldi et al., 2018). In this way, the project for the design of a collective greenhouse represents a technological solution developed by a public university to respond to the specific needs of a society with limited resources. The study presented focuses its reflections on experiences and challenges based on this initiative.

The questions guiding this research are the following:

What are the experiences of working with design thinking for the development of a collective greenhouse in a rural community in Bolivia?

How can journey maps be implemented to improve user involvement when developing a collective greenhouse in the Bolivian agricultural sector?

Given the scarcity of research on the application of design thinking tools in industries such as agriculture, the present research is assumed to be exploratory in nature (Carlgren, Elmquist, et al., 2016). It seeks to illustrate the relevance and versatility of the journey map as a tool for early-stage farmer involvement, technology, and product development (Howard, 2014; Siggelkow, 2007).

Empirical context

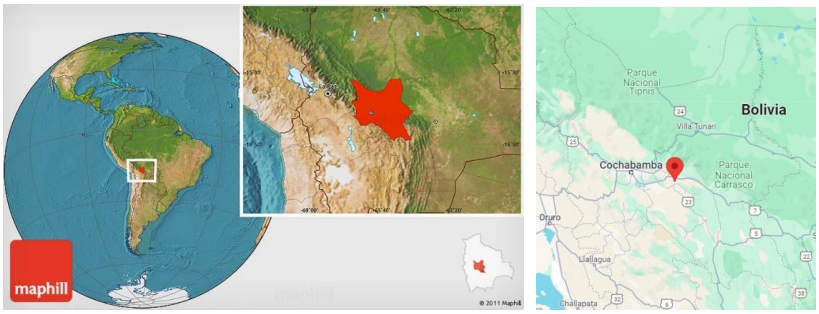
The empirical context of this study is based on a rural initiative to support two communities of a municipality managed by a public university in Bolivia, which seeks to respond to the needs demanded by society, as part of its mission of interaction through the democratization of knowledge and the development of technology. Since 2007, the university through a unit of technology transfer (UTT) has embarked on the creation of interactive learning spaces known as 'cluster initiatives' as part of a strategic effort to improve its innovation processes and broaden its social impact. According to (Trojer et al., 2015), the importance of these spaces lies in the fact that cluster-based learning could improve the positioning of firms and producers within value chains of different scales (local, national, continental, or global), while contributing to the alleviation of income disparities and the reduction of the number of people living in absolute poverty. The university unit is responsible for promoting and managing these cluster initiatives between small and medium-sized enterprises (SMEs) and the University's scientific and technological capabilities (Acevedo et al., 2015).

Currently, two cluster initiatives are being promoted by this university unit, one in the food sector and the other in the green technologies sector, the latter with a circular economy approach. A central activity for the unit is to support SMEs in the design of prototypes for the purpose of improving production processes. Previous studies carried out with the clusters indicate that an important factor for obtaining satisfactory prototypes is the inclusion of the end user in all the processes of the design and development of a prototype (Fischer et al., 2020; Grates et al., 2019).

Since 2021, the cluster initiatives have been using Design Thinking as a method to support the management level to carry out effective and more user-centered prototyping processes (Ben Mahmoud-Jouini et al., 2016; Cagnin, 2018; Knight et al., 2020; Malins, 2011). The university unit is still learning about the most advisable implementation of the Design Thinking method for developing successful prototypes. In that sense this research proposes to explore the possibilities of using a holistic design thinking tool such as the journey map to better understand user needs and to involve and engage them in all phases of development of innovative-oriented technologies. The initiative of a collective greenhouse prototype stems from the need to protect the agroforestry production of pests and the effects of climate change in the two communities of Catachilla and Rancho Nuevo that are located in Santivañez municipality of Cochabamba, Bolivia, as showed in Figure 1. The main climatic phenomenon suffered by the producer families of these communities is drought, which affected 55% of 16 families who claim to have suffered crop losses due to drought in the period 2020 - 2021. This situation in previous years (2013 - 2018) in both communities was more severe, with crop losses in plots, between 50 and 100% (Ricaldi et al., 2018). Due to these severe crop losses and in the context of water scarcity, the families have turned to cultivation in home gardens to try and ensure their food security (DICyT, 2022). The families who are committed to the agroforestry garden experiences are called "ECOHUERTOS producers' group" that inspire the learning routes, tell stories, and develop narratives that encourage and promote agroecological production in agroforestry systems (Ricaldi, 2023). However, the home gardening solution has created a new problem with the appearance of pests of birds and rodents. The communities are therefore developing a collective greenhouse prototype as a new and more sustainable cultivation alternative. This prototype will be a learning space for the producer families, where they will be able to evaluate and create the

adequate conditions for self-sustainable production.

Figure 1. Satellite view of Santivañez municipality in Cochabamba city of Bolivia.



Note: The left picture shows the geographical location of Cochabamba city of Bolivia, and the right picture indicates the local site of Santivañez municipality.
Source: http://www.maphill.com/ (review in 2024).

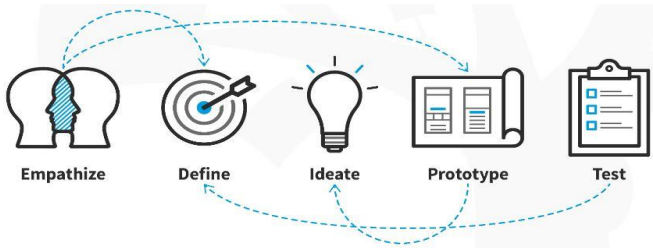
Theoretical Framework

1. *Design Thinking*

Design is an interdisciplinary domain that employs approaches, tools, and thinking skills that help designers devise more and better ideas toward creative solutions (Kelley & Kelley, 2013). The term "design thinking" refers to cognitive processes of design work (Cross, 2011)–or the thinking skills and practices designers use to create new artifacts or ideas and solve problems in practice.

The Stanford model has five phases or stages of design thinking shown in Figure 2, also referred to as modes, which are worked through towards problem solutions or resolutions. These five modes are: empathize, define, ideate, prototype, and test.

Figure 2. Design Thinking: A 5-Stage process.



Source: Interaction-design.org (review in 2023).

Stage 1: Empathize

Empathy is where a designer begins to understand a situation or problem from the perspective of others involved, like users and their actions (Pap et al., 2019). In design, empathy speaks to the user, attempting to understand what matters to them (Kolko, 2014).

Stage 2: Define

In the definition phase, the collected information is processed, and the challenge is defined (Antoljak & Kosović, 2018). It focusses on analyses the observations and synthesizes them to define the core problems identified called problem statements. Defining a problem requires examination of its complexities and variables. The creation of personas can help to keep the efforts of human-centred before proceeding to ideation.

Stage 3: Ideate

After previously developing a problem definition, the Ideate stage focuses on generating a range of ideas and approaches to a problem. Designers must hold judgment and jump into an open-minded idea exploration. The solid background of knowledge from the first two phases means you can start to "think outside the box", look for alternative ways to view the problem and identify innovative solutions to the problem statement you've created. Brainstorming is particularly useful here.

Stage 4: Prototype

This is an experimental phase. The aim is to identify the best possible solution for each problem found. It consists of producing some inexpensive, scaled-down versions of the product (or specific features found within the product) to investigate the ideas generated. This could simply involve paper prototyping. Whatever a designer creates must be tested for users. So, prototyping is inextricably linked to the phase that follows–Test. The Stanford Design School philosophy states, “prototype as if you know you’re right, but test as if you know you’re wrong” (Plattner, 2015).

Stage 5: Test

In the Test stage, a prototype is shared with an audience of stakeholders or users. A designer might implement their prototype in real conditions that can be carried out at all stages of the process and the purpose is to get feedback (Antoljak & Kosović, 2018) with users, and observe, interview, survey, or ask them about the prototype. Although this is the final phase, design thinking is iterative: Teams often use the results to redefine one or more further problems. So, you can return to previous stages to make further iterations, alterations, and refinements – to find or rule out alternative solutions.

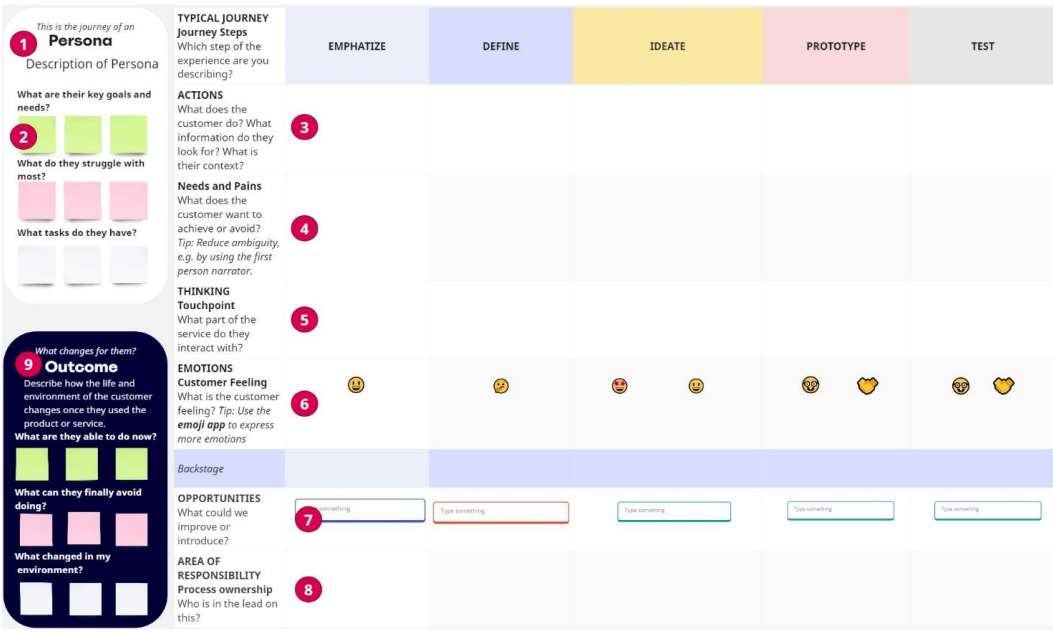
Overall, the Design Thinking stages are a way to structure the design process which contribute to the entire design project, using these sequential steps. The goal throughout the process to gain the deepest understanding of the users and what their ideal solution/product would be.

2. *User Journey maps (Also called Customer Journey Maps)*

Journey maps, which are developed in collaboration with actual users or customers are undertaken with their particular perspective in mind, provide a graphical representation of the different stages, interactions, and feelings that mark a user's experience (Actions) when using or

purchasing a particular product or service, and thereby include various points of contact between the user and either the company or a specific product offering (Touch Points) (Calabretta & Gemser, 2015; Howard, 2014). In Figure 3, there is a visual description of the user journey map in relation to the different design thinking phases.

Figure 3. Procedure and template of User Journey map.



Source: template adapted from Miro (2024).

The research design follows (Lewrick et al., 2020) steps for developing and implementing the user journey map.

• Step 1: Consists of choosing a persona to be used in the journey map and to share the story of the persona with the design team.

• Step 2: Then choose a scenario or job to be done. What does the persona do and what is the context? It may be an end-to-end experience or a part of it.

• Step 3: Define what happens BEFORE, DURING, and AFTER the actual experience to make

sure that the most important steps are included. Mark all experience steps (e.g. using Post-its). It is easier to compile an overview on the meta-level before expanding and elaborating.

• Step 4: Decide which interactions should be assigned where and how. The template gives us space for the typical journey and the respective actions.

• Steps 5 & 6: Supplement what the persona thinks (Step 5) and the emotion he/she feels (Step 6). Capture the emotional status (positive and negative) of each step with coloured glue dots or emoticons.

• Steps 7 & 8: Define potential areas of improvement (Step 7) and the people responsible for the action/ process within the organization (Step 8). Once a clear picture of the experience emerges, the design team automatically comes up with questions, new insights, and potential improvements.

• Steps 9: Describe the outcomes of changes and improvements after the experience.

The user journey map is usually developed and used in the “empathize,” “define,”, "ideate" and “prototype” design thinking phases. In this case, we have applied the journey map in the “test” phase as well to include the user experiences of testing the greenhouse prototype.

The application of UJM during and after the development of the prototype allows us to compare the expected results generated in empathize phase with the results obtained during the prototype and test phase. In this way we will be able to identify if the communication was sufficient throughout the development of the greenhouse or if there were any problems along the way. The user journey experience is defined as the user’s subjective interpretation of what a product, service or company represents and offers (Meyer & Schwager, 2007) in terms of usability: effectiveness (whether users can achieve what they want to do), efficiency (how long it takes them to achieve it) and satisfaction (their feelings and attitude towards the product) (Nenonen et

al., 2008). Through this learning path that is generated with the Journey map, with relevance to show the whole user experience in all Design Thinking phases.

3. *User involvement*

Currently, studies in the innovation field recognize that user participation must be more active for technological development (Hienerth et al., 2014). In this sense, the role of the user in innovation processes is studied on different fronts: users as a source of information, and users as co-creators, and even as innovators (Cui & Wu, 2016; Fang, 2008; Von Hippel & Katz, 2002). Firstly, users as a source of information, a passive role of the user is still delineated, because the company takes full responsibility for the design and development process, and uses the information provided by the user to improve the understanding of their needs and desires. Secondly, as co-creators (or co-developers), users contribute to the generation of ideas and are responsible for specific tasks during development or form part of the company's development team (Dahlsten, 2004; Fang, 2008). In short, they actively participate in joint problem-solving processes. Thirdly and finally, as innovators, users can also be responsible for creating new products, often by adapting existing products to their specific realities (Bogers et al., 2010; Von Hippel, 2005).

User contributions have been found to provide ideas that are more creative, easier to implement, and more valued by users (Hölzle & Rhinow, 2019; Kristensson et al., 2004; Poetz & Schreier, 2012). In contrast, ideas developed by technology developers and experienced users tend to emphasize feasibility. In this way, user involvement proves capable of amplifying the potential of both the firm to be innovative and the technology to be successfully adopted (Douthwaite et al., 2001; Hienerth et al., 2014). However, user involvement can lead to information overload, bringing more fuzziness than focus to the process (Hölzle & Rhinow, 2019; Hoyer et al., 2010).

Thus, there is an urgent need for new methods and the application of tools that better integrate and reflect the diversity of actors and technologies involved. These methods are sought to enable us not only to access or collect more information, but to design a process that ensures alignment with all possible stakeholders involved.

According to (Rohracher, 2003), it has been shown that users play an important role at several levels, such as: (1) the interactions between the user and other users; (2) the technology-user interaction and its application in everyday life and processes; and (3) the user-producer interaction. Thus, it was deemed convenient to apply journey maps as they can easily provide information on all these interactions, as well as improve the possibilities of user-producer relationships and thus increase the capacity for innovation (Brown, 2008; Micheli et al., 2019).

Research Methodology

A sole case study was conducted where the user journey map is applied to follow the process of the development of a collective greenhouse prototype for producers of a local community in Bolivia. This initiative was proposed to mitigate the effects of climate change (resilience), promote the social inclusion and sustainability of agriculture production in rural areas.

This research presents one application of user journey map at the collective greenhouse initiative with three interventions realized by UTT researchers' team to Ecohuerto producers, to complete the journey before, during and after the experience. Table 1 shows the methodological summary.

Table 1. Research design of the application of the User Journey map

The application of the user design maps throughout the greenhouse	Aim	Data sources	Date and location
Intervention 1 DT phase: empathize (Before the development of prototype)	Explore the use of user journey maps by producers as a tool for innovation management, to provide insights for the development of a greenhouse prototype.	The responsible research facilitator at the technology transfer unit and the producers developed a persona and scenario (Step 1 and 2 of the Journey map) based on an interview with 5 Ecohuertos agricultural producers (3 from Catachilla community and 2 from Rancho Nuevo community).	Date: June 1st of 2023. Length of time: 45 minutes Place: Catachilla community of Santivañez Municipality
Intervention 2 DT phase: define, ideate and prototype (During the development of prototype)	Understand which pain points an innovative oriented technology may solve. In summary, to evaluate the activities, thoughts, and feelings during the development of the greenhouse prototype.	One workshop facilitated by three researchers of UTT to 14 farmers of two rural communities (5 from Catachilla and 9 from Rancho Nuevo)	Date: June 29th of 2023. Length of time: 75 minutes Place: Catachilla community of Santivañez Municipality.
Intervention 3 DT phase: test (After the development of prototype)	Identify the challenges and opportunities after the use of the collective greenhouse prototype in the agroforestry production.	One workshop facilitated by two researchers of UTT and one researcher of Centre for higher education (CESU) to 14 farmers of two rural communities (5 from Catachilla and 9 from Rancho Nuevo) Same participants as during intervention 2.	Date: January 11th of 2024. Length of time: 75 minutes Place: Catachilla community of Santivañez Municipality.

Intervention 1 of user journey map was developed by one interview to empathize with producers, where three producers are from Catachilla community two from Rancho Nuevo community.

Intervention 2 of user journey map consisted of one workshop to define the final model of collective greenhouse.

Intervention 3 evaluate the experience after building the greenhouse prototype. The feedback obtained in the final workshop shows the effects of the prototype to improve their environmental productive conditions.

Semi-structured questionaries are realized to follow the sections of User Journey maps during the workshops. Interview guides are attached in Annex 1 and 2.

Regarding the ethics consideration, the UTT researchers asked the productors for permission to conduct interviews regarding their experience of greenhouse development.

Results

The intended outcome of applying the user journey map (UJM) in the chosen context was to integrate the diverse ideas and thoughts of the team (producers and researchers) to find a solution regarding a potential greenhouse based on a well-defined problem. The problem statement allows to define the minimum technical requirements of prototype, which evaluation will consist in three categories: fit, aesthetics and functionality (Olivares U. & Arévalo G., 2022).

The journey map in this case focuses specifically on the interaction between the user and the technology. That is, it highlights how the technology will influence the producers' journey, serving as a tool to confirm the potential of the technology and reduce technological uncertainty (Tatikonda & Stock, 2003). In other words, the journey map will allow users to be familiar with the technical specifications and irrigation system of the greenhouse, thus reducing the levels of those technological uncertainties. This way, the full potential of the greenhouse will be exploited thanks to the 'learning by doing' technique. Additionally, this application emphasizes the user's feelings about the problems and solutions shown on the map, thus going beyond "how" the user sees the applicability of the potential solution and suggesting "why" they use it or not. In this way a brief explanation of the greenhouse is made using a physical and virtual prototype, so that the users can better understand the application of the greenhouse while describing their journey, before launching the final prototype, thus creating a deeper bond between the user and the greenhouse prototype.

During the application of the user journey map, the design thinking stages are followed as the strategy of sequential steps for the development of prototypes. The actions that emphasize

before, during and after the process of the development of the collective greenhouse are described through three interventions, explained in the following section. Figure 4 shows the picture of one workshop realized during the development of the greenhouse.

Figure 4. Workshop with producers applying the User Journey Map to define the final design of collective greenhouse.

Source: UTT (2023).

Intervention 1 of User Journey Map – Before the development of prototype

The first intervention is part of empathize process, in which interviews were conducted with five producers, three from the community of 'Catachilla' and two from the community of 'Rancho Nuevo'. This first interview was the first direct contact between the researchers and the producers, the idea was to encourage them to answer some general questions to know more about their lives, customs, and expectations about the proposal of the project for the development of a greenhouse prototype. Based on the interviews, the Persona and Scenario were developed and described as seen in Figure 5.

The chosen persona to be used in the user journey map is an agroecological producer with an average age of 19 to 77 years, who lives in a rural community of Santivañez Municipality. Their main sources of income come from harvesting and selling fruits and vegetables and raising farm animals. The producer lives in a scenario in which the climate conditions change, which transforms the productive and food reality of the families of Santivañez. Therefore, the collective

greenhouse emerges as a strategy to face climatic phenomena, especially drought and pests of small animals.

Figure 5. Description of story of persona and scenario

Source: Left figure source is Author's own creation (2024), and right figure source is UTT (2024).

The questions from step 3 to step 8 were focused on the thoughts and feelings before and after the implementation of the greenhouse to improve the agroforestry production and to manage their shared spaces among 14 family's producers of both communities. Table 2 shows some quotes of producers' responses to know more about their expectations and thoughts BEFORE the development of greenhouse prototype.

In this first interaction, the producers explained at researchers about their problems with pests and climate change. Based on this background, the researchers came up with the idea of building

a greenhouse, with an easy functionality and maintenance to understand by producers.

Table 2. Quotes of responses of Producers BEFORE the development of Greenhouse prototype

TOPIC	Quotes
Needs and pains	*"There are weevils in hot weather". (Producer 2)*
	"Wind or frost. And Hailstorm because of the holes ". (Producer 4)
	"Need to combat bird attacks". (Producer 1)
Thoughts	*"It is important our participation in interviews and workshops to show our specific requirements" (Producer 3).*
Emotions	*"Happiness, joy" (Producer 1).*
	"Curiosity" (Producer 5)
Opportunities	*"It is an opportunity for everyone in the Collective to have fresh products" (Producer 1).*
Area of Responsibility	*"Internal meetings with the entire group" (Producer 2).*

Intervention 2 of User Journey Map- During the development of prototype

The second intervention covered the processes of define, ideate, and prototype as shown in Figure 6 and consisted of a workshop applying the UJM to evaluate the activities, thoughts, and feelings during the development of the greenhouse prototype. During the workshop, as part of the define phase, the producers defined the final concept model of the greenhouse. In the ideate phase they visualized a virtual and mock up prototype before starting the development process. And in the prototype phase they defined the activities in which will be involved for the development of the greenhouse prototype. Additionally, they created a list of materials and instruments necessary for the assembly of greenhouse. The quotes from the producers, as shown in Table 3, indicate a need for more commitment with some activities to reach the final goal of collective greenhouse.

Figure 6. Activities realized in define, ideate, and prototype phases of Design Thinking.

Source: UTT (2023).

Table 3. Quotes of Producers' responses DURING the development of Greenhouse prototype

TOPIC	Quotes
Needs and pains	*"Avoid excessive water consumption for irrigation". (Producer 1)*
	"Have a space protected from cold, hall, wind and various pests". (Producer 2)
	"Produce various products all year round". (Producer 3)
	"Avoid the use of pesticides to prevent pests". (Producer 5)
	"Prevent plants from dying during the cold season". (Producer 4)
	"Organization for irrigation, weeding, sowing, harvesting, distribution of spaces ". (Producer 7)
	"To have an efficient irrigation system". (Producer 6)
	"Need to be organized in the preparation of bio inputs to protect the plantations". (Producer 9)
	"Organizational improvements to manage water, irrigation and watering". (Producer 8)
	"Preventive management of bio-inputs to avoid pests such as aphids". (Producer 10)
Thoughts	*"Support from the Mayor's office with gravel and sand" (Producer 1).*
	"We are excited because we will be able to produce more fruits and vegetables in greenhouse during the cold season" (Producer 5).
	"Models are taken from greenhouse experiences for soil preparation" (Producer 3).
	"Use of black rubber, composts and soil to prepare the soil" (Producer 2).
	"Thick pipe, fertilizer and seeds" (Producer 4).
	"Construction of internal boards" (Producer 7).
	"Greenhouse elements" (Producer 2).
	"Participation in the assembly of Greenhouse" (Producer 6).
Emotions	*"Curiosity, uncertainty" (Producer 1).*
	"Opportunity, hope, uncertainty" (Producer 5)
	"Commitment, collaboration, solidarity" (Producer 3)
Opportunities	*"The nursery is necessary and beneficial. Expand over time with other greenhouses" (Producer 3).*
	"We can test Staggered production and continuous production" (Producer 1).
	"Better feeding conditions. Year-round production because of the climatic conditions of the greenhouse will help us" (Producer 2).
Area of Responsibility	*"Participate in visits to research centres to view greenhouse model options" (Producer 1).*
	"Book of minutes of meetings" (Producer 2).
	"All producers must participate in the workshops to define the model and minimum requirements of the greenhouse" (Producer 3).

"Management of elements to be put by the producers to prepare the greenhouse soil" (Producer 5).
"Participation of all producers in greenhouse maintenance and use training" (Producer 4).
"All growers participate in the greenhouse assembly and installation process" (Producer 6).

Intervention 3 of User Journey Map- After the development of prototype

The third and final intervention took place during a second workshop, after the development of the prototype, and covers the test phase. The workshop began with the researchers testing the function of collective greenhouse and evaluate the resistance, versatility, and efficiency of this space and then the producers expressed their thoughts and feelings when testing the functionality and compositions of the greenhouse (see Table 4 for a selection of quotes from the producers). During this intervention the producers recognized some challenges like greenhouse agreement location, agreement management to prepare the greenhouse soil, some physical limitations, and the humidity conditions inside the greenhouse. In terms of opportunities, the producers explained how they will be able to produce fresh products and increase their production thanks to the collective greenhouse. Additionally, the greenhouse provides better feeding conditions and a space to test different production systems like staggered production and continuous production as exposed in Figure 7.

Figure 7. Activities realized in test phase of Design Thinking

Source: UTT (2023).

Table 4. Quotes of Producers' responses AFTER the development of Greenhouse prototype

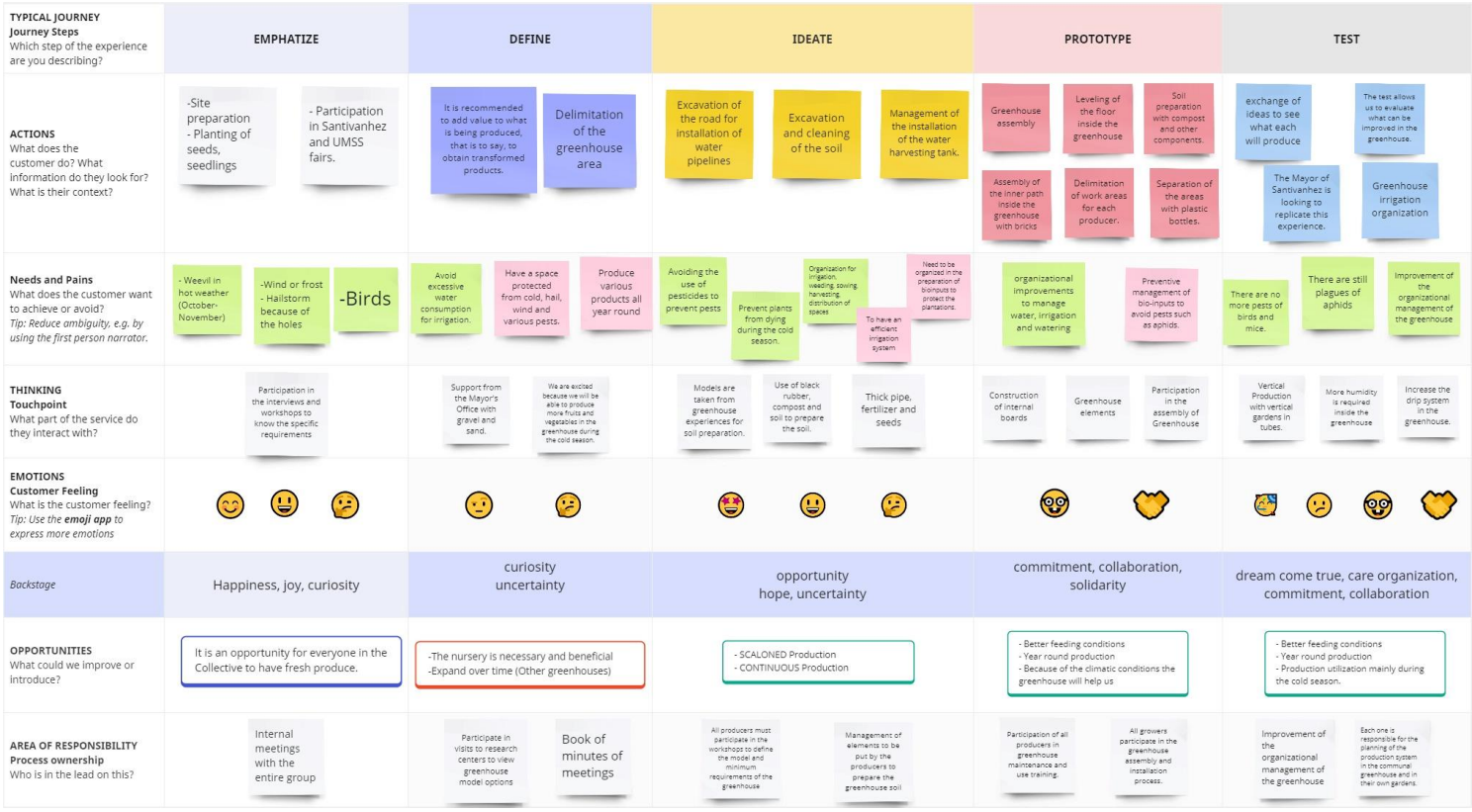
TOPIC	Quotes
Needs and pains	*"There are no mores pests of birds and mice". (Producer 2)*
	"There are still plagues of aphids ". (Producer 4)
	"Improvement of the organizational management of the greenhouse". (Producer 1)
Thoughts	*"Vertical production with vertical gardens in tubes" (Producer 5).*
	"More humidity is required inside the greenhouse" (Producer 3).
	"Increase the drip system in the greenhouse" (Producer 4).
Emotions	*"Dream of come true, care organization" (Producer 1).*
	"Commitment, collaboration" (Producer 5)
Opportunities	*"Better feeding conditions. Year-round production" (Producer 1).*
	"Production utilization mainly during the cold season" (Producer 3).
Area of Responsibility	*"Improvement of the organizational management of the greenhouse" (Producer 2).*
	"Each one is responsible for the planning of the production system in the communal greenhouse and in their own gardens" (Producer 5).

The final journey map based on the three interventions.

The three interventions of the journey map application are summarized and described in Figure 8. The map shows the needs and pains, thoughts, and emotions of the producers during each step, the last one presented with emoticons to show graphically their emotions.

Regarding the opportunities and area of responsibility assigned for each action or process, allows to manage a good organisation of collective greenhouse and to look opportunities for continuous improvement. In this case producers show their main responsibilities of the activities realized in each Design thinking phase.

Figure 8. Application of User Journey map to Agroecological Producers (users) "Ecohuertos" of Santivañez



Source: Author's own creation (2024).

The purpose of User Journey map template is to show all the experience before, during and after the development of the prototype. This is reflected in each phase of Design Thinking which show the results of qualitative data obtained in semi-structured interviews and the two workshops realized at producers. The facilitators of UTT built this template with all data obtained of producers' answer. Researchers of the metalmechanic research center ‘Program of development and manufacturing technologies’ (PDTF-UMSS) were responsible of the design and development of the prototype. The active participation of the producers in workshops, interviews and assembly process allows to get fruitful feedback to get the final design of the prototype and to learn some practical issues for the use and maintenance of the greenhouse.

Figure 9 describes the Step 9 of outcomes about life and environment of user after the used of collective greenhouse prototype. Some changes that the producers experienced include the increasing of number of plantations, the sprinkler irrigation method for water consumption and the annual production planning because now they could test different varieties of fruits and vegetables to produce during the whole year.

Figure 9. Description of outcomes about life and environment of user changes.

Source: Author's own creation (2024).

Discussion

The experience of using a design thinking tool such as User Journey maps, which facilitates the identification of emerging user needs and desires, opens a range of different purposes for the use of the tool. So, the lessons learned are based on the application of the UJM at producers, who follow the 5 phases of Design Thinking as part of the process for the development of a technology. Thus, the activities, motivations and barriers described in the tool are divided into the five phases of Design Thinking that are empathize, define, ideate, prototype, and test. The phase of empathize shows the experience before the development of the greenhouse, phases of

define, ideate and prototype represents the experience during the development of greenhouse and the phase of test shows the experience after the implementation of the greenhouse.

The application of the user journey map together with producers brings to light specific sources of misunderstandings on the part of primarily users and researchers. The fact that all stakeholders, and producers, recognize their own 'blind spots' and possible deficiencies will help improve the organizational processes at the technology transfer unit at the university.

Thus, the experiences based on the applying of one design thinking tool like User Journey map are divided in the following three dimensions: activities, motivations, and barriers.

The user involvement in the following activities like: company visits to define the greenhouse model (Before the experience), assembly and training of usability and maintenance of greenhouse during the prototyping phase (During the experience), and productivity monitoring and evaluation of use during the testing phase (After the experience), expand the potential for the unit of transfer of technology to be innovative and for the technology to be successfully adopted (Douthwaite et al., 2001; Hienerth et al., 2014).

The motivations of both groups (producers and researchers) can be summarized as follows: Before the experience to have a space that allows a solution to pests and harvesting in changing climatic conditions, During the experience an opportunity to develop other greenhouses based on the lessons learned regarding technical and agricultural aspects. Additionally, the improvement of productive capacity and family economy are motivations to increase their incomes based on continuous year-round production, that at the same time allows to improve feeding conditions. After the experience it is expected that there will be no more pests of birds and mice. Also, they project to have a space to test different irrigation and harvesting systems for a variety of plantations.

The barriers regarding the case study are summarized in the inconsistent participation of the whole group in the workshops, difficulty in reaching consensus on joint decisions and organizational management of the producers for the use and maintenance of the greenhouse. One of the main barriers of using the UJM tool consists in the fraught encounter between "scientific" knowledge (of technology developers) and "experiential" knowledge (of farmers) (Liedtka, 2015). This is due to a phenomenon whereby some farmers are disconnected from the challenges of everyday practice (Higgins & Bryant, 2020), so they are skeptical of the benefits of technologies developed by scientists or entrepreneurs. After the experience producers identified other barriers like far innovation space for one community, long project execution time limited the testing of production on winter season and organizational management of the greenhouse.
The application of User Journey Maps in this type of context of rural communities was effective in fostering multidisciplinary collaboration and knowledge sharing among the stakeholders involved in the research. The producers recognized certain barriers that were important to address and overcome in the development process, for instance the questions of protocol guide, in which the technical words are changed by generally understandable sentences. In this case, the user involvement as a source of information represents a key challenge for researchers to fully understand and utilize user inputs to generate innovative product designs (Cui & Wu, 2017).
Another adaptation to improve the inconsistent participation of the whole group consists of using a tracking notebook and fines in case of consecutive non-attendance of more than 3 days.
Regarding the organizational management of producers for the use of greenhouse started with a consensus to divide up the land areas. Concerning the maintenance of the greenhouse, we have yet to define the frequency and the definitive assignment of responsibilities.
Another challenge of this type of research project lies in the fact of how to integrate user

perspectives at an early phase, to contribute to the development of a technology adapted to a specific context with limited resources. By involving the producers as co-creators and integrating their perspectives in the early empathy phase we were able to create a fluid communication and coordination journey between the different stakeholders of the greenhouse project. Thus, Co-creation as an inclusive approach empowers customers to express their perceptions, ideals, and subconscious feelings about a product, service, or experience in the early process (Dalton & Kahute, 2004). The application of the journey maps brought to light misunderstandings between user and researchers and allowed the stakeholders to focus on "the problem space" (Dorst, 2011). In that sense, the coalition-building and collaboration between formal and informal groups allows to empower local communities to develop a distinctive food system identity that promotes community support, collaborative networks, and food justice at the municipality level (Ben-Othmen & Kavouras, 2022). All of this is channeled within the prototype greenhouse developed, which is a learning space that guarantees an optimal microclimate to ensure continuous annual production.

According to (Seidel & Fixson, 2013) when multidisciplinary teams coordinate well then can more successfully apply design thinking in their projects as they are aware of the limits of brainstorming and can move from more to less reflective practices when seeking to combine methods. This is notable in the greenhouse project as the involved stakeholders were effective in fostering multidisciplinary collaboration and knowledge sharing. The empirical experience and endogenous knowledge of the producers influenced the selection of appropriate mechanisms for greenhouse development as well as identifying a suitable agricultural environment.

Conclusions

The experience working with user journey maps for developing a collective greenhouse following the stages of design thinking proved to be very challenging because of the quite complex project. The complexity is attributed that the stakeholders had different ideas and expectations of how a greenhouse can benefit the rural community, and it was, at times, difficult to reach consensus on joint decisions. For instance, deciding on the location of the greenhouse proved to be difficult, as was the decision on the organizational management for the use and maintenance of the greenhouse. Other challenges concerned the project time that was prolonged because of limitations with testing the greenhouse during the winter season and the greenhouse assembly process because the producers weren't trained for this construction work, so it became physically challenging.

It is important to consider that by working with journey maps as part of the greenhouse prototype the university unit and their facilitators changed their design processes to increase user involvement and strengthen stakeholder engagement. This ultimately created unexpected difficulties as well as opportunities for pinpointing friction points and creating a deeper bond between the researchers and producers.

In this case study, the participation of producers during the process of defining the concept and setting up the greenhouse was crucial for the endogenous knowledge they transmitted for the optimization of resources and for the management of agricultural production within the greenhouse. Alongside the barriers identified, the stakeholders identified several promising outputs for the greenhouse. These includes a space for harvesting in changing conditions and testing natural products that replaced pesticides and an overall improvement of a sustainable and productive agricultural environment increasing the producers' incomes based on continuous

year-round production and providing a sufficient food supply. Additionally, both researchers and producers learned about technical issues of assembly and installation process of greenhouse, and agricultural issues related to irrigation and harvesting systems. These findings will be significant when providing opportunities to replicate the collective greenhouse prototype in other communities.

In summary, user journey maps offer broader lenses needed to manage innovation in a more complex context (Hamilton & Price, 2019). In the case of cluster and rural initiatives, journey maps stand out as an effective communication tool that aids knowledge transfer from user to developer, this being a first step towards integrating the user into the development process (Cui & Wu, 2017). Thus, an overview of how user involvement in journey map research and development processes can not only guide such involvement, but also facilitate collaboration among different stakeholders of this technology innovation initiative.

A broader role of users must be considered, as the agricultural producers provide a unique understanding and knowledge of the context, and the adoption and use of the greenhouse will ultimately affect and transform their current routines. Importantly, the role of the university unit is not "only" to listen to users as a source of information, but to enable them to be co-creators or even innovators themselves (Cui & Wu, 2016). The democratization of the design process of innovative technologies will enable users to improve the value propositions of their products and services, and eventually provide a more sustainable and resilient community. For that reason, the university conducted various training courses on the use and maintenance of the greenhouse so that the producers of this rural community will become autonomous and self-sufficient.

Consequently, design thinking tools such as journey maps offer unprecedented potential to foster new value propositions that align different stakeholders and resources, while focusing on the

value presented to users. The journey maps function as an important tool for exploring user experiences, gathering feedback, and even enabling collaborators to rethink the problem space. In this way journey maps seek to create more empathy with users than in promoting creativity as a means of enterprise communication (Carlgren, Rauth, et al., 2016; Dell'era et al., 2020). Likewise, by thoroughly engaging in understanding users and the journeys they undertake, many other requirements for complementary technologies or their adoption by important stakeholders can be uncovered. In this case study, the participation of producers during the process of defining the concept and setting up the greenhouse was crucial for the endogenous knowledge they transmitted for the optimization of resources and for the management of agricultural production within the greenhouse.

The use of Design Thinking (DT) approach can improve the performance of firms (Suci et al., 2022) and rural initiatives in the development of products in contexts of limited resources. This, due to the user-focus, creative problem-solving, experimentation, and iteration (Björklund et al., 2020) to continuously improve the development of a product, service, process, with high utility that meet the needs of users (Chen et al., 2018). In this way, DT search for "integrative environments" that encourage researchers to redefine problems in the search for integral solutions. It also recognizes the potential of the journey map tool to facilitate engagement and discussion not only with users, but also with the public at large.

References

Acevedo, C., Cespedes, W. M. H., & Zambrana, J. E. (2015). “Developmental University” approaches in developing countries: Case of the Universidad Mayor de San Simon, Bolivia. In *Developing Inclusive Innovation Processes and Co-evolutionary approaches in Bolivia* (pp. 53–72). Blekinge Institute of Technology.

Antoljak, V., & Kosović, M. (2018). Design thinking za nedizajnere – kako riješiti poslovne probleme i uspješno inovirati. *Zagreb: Školska Knjiga. (in Croatian)*.

Ben Mahmoud-Jouini, S., Midler, C., & Silberzahn, P. (2016). Contributions of Design Thinking to Project Management in an Innovation Context. *Project Management Journal*, *47*(2), 144–156. https://doi.org/10.1002/PMJ.21577

Ben-Othmen, M. A., & Kavouras, J. H. (2022). Developing a community-based local food system in Will County, Illinois: Insights from stakeholders’ viewpoints. *Journal of Agriculture, Food Systems, and Community Development*, *11*(2), 263–283. https://doi.org/10.5304/jafscd.2022.112.018

Berthet, E. T., Hickey, G. M., & Klerkx, L. (2018). Opening design and innovation processes in agriculture: Insights from design and management sciences and future directions. *Agricultural Systems*, *165*, 111–115. https://doi.org/10.1016/J.AGSY.2018.06.004

Björklund, T., Maula, H., Soule, S. A., & Maula, J. (2020). Integrating Design into Organizations: The Coevolution of Design Capabilities. *California Management Review*, *62*(2), 100–124. https://doi.org/10.1177/0008125619898245

Bogers, M., Afuah, A., & Bastian, B. (2010). Users as innovators: A review, critique, and future research directions. In *Journal of Management* (Vol. 36, Issue 4, pp. 857–875).

https://doi.org/10.1177/0149206309353944

Brown, T. (2008). *Design Thinking. In Harvard Business Review*. *86*(6), 84–92.

Busse, M. , Doernberg, A. , Siebert, R. , Kuntosch, A. , Schwerdtner, W. , König, B. , & Bokelmann, W. (2014). *Innovation mechanisms in German precision farming. Precision agriculture*. *15*, 403–426. https://doi.org/10.1007/s11119-013-9337-2

Cagnin, C. (2018). Developing a transformative business strategy through the combination of design thinking and futures literacy. *Technology Analysis & Strategic Management*, *30*(5), 524–539. https://doi.org/10.1080/09537325.2017.1340638

Calabretta, G., & Gemser, G. (2015). Integrating Design into the Fuzzy Front End of the Innovation Process. *Design Thinking: New Product Development Essentials from the PDMA*, 105–124. https://doi.org/10.1002/9781119154273.ch8

Carlgren, L., Elmquist, M., & Rauth, I. (2016). The Challenges of Using Design Thinking in Industry – Experiences from Five Large Firms. *Creativity and Innovation Management*, *25*(3), 344–362. https://doi.org/10.1111/caim.12176

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing Design Thinking: The Concept in Idea and Enactment. *Creativity and Innovation Management*, *25*(1), 38–57. https://doi.org/10.1111/caim.12153

Chen, S., Benedicktus, R., Kim, Y., & Shih, E. (2018). Teaching Design Thinking in Marketing: Linking Product Design and Marketing Strategy in a Product Development Class. *Journal of Marketing Education*, *40*(3), 176–187. https://doi.org/10.1177/0273475317753678

Cross, N. (2011). Design Thinking: Understanding How Designers Think and Work. *Berg Publishers.* . https://doi.org/10.5040/9781474293884

Cui, A. S., & Wu, F. (2016). Utilizing customer knowledge in innovation: antecedents and

impact of customer involvement on new product performance. *Journal of the Academy of Marketing Science*, *44*(4), 516–538. https://doi.org/10.1007/s11747-015-0433-x

Cui, A. S., & Wu, F. (2017). The Impact of Customer Involvement on New Product Development: Contingent and Substitutive Effects*. *Journal of Product Innovation Management*, *34*(1), 60–80. https://doi.org/10.1111/jpim.12326

Dahlsten, F. (2004). Hollywood wives revisited: a study of customer involvement in the XC90 project at Volvo Cars. *European Journal of Innovation Management*, *7*(2), 141–149. https://doi.org/10.1108/14601060410534384

Dalton, J., & Kahute, T. (2004). Why Empathy and Customer Closeness is crucial for Design Thinking. *DMI*, *27*(2). https://doi.org/10.1111/drev.12004

Dell'era, C., Magistretti, S., Cautela, C., Verganti, | Roberto, & Zurlo, F. (2020). *Four kinds of design thinking: From ideating to making, engaging, and criticizing*. https://doi.org/10.1111/caim.12353

DICyT, U. (2022). *Prospectiva. Revista científica DICyT-UMSS*.

Dorst, K. (2011). The core of "design thinking" and its application. *Design Studies*, *32*(6), 521–532. https://doi.org/10.1016/j.destud.2011.07.006

Douthwaite, B., Keatinge, J. D. H., & Park, J. R. (2001). Why promising technologies fail: The neglected role of user innovation during adoption. *Research Policy*, *30*(5), 819–836. https://doi.org/10.1016/S0048-7333(00)00124-4

Fang, E. (2008). Customer Participation and the Trade-Off Between New Product Innovativeness and Speed to Market. *Journal of Marketing*, *72*(4), 90–104. https://doi.org/10.1509/jmkg.72.4.090

Fischer, B., Peine, A., Östlund, B., & Heyn, P. C. (2020). The Importance of User Involvement:

A Systematic Review of Involving Older Users in Technology Design. In *Gerontologist* (Vol. 60, Issue 7, pp. E513–E523). Gerontological Society of America. https://doi.org/10.1093/geront/gnz163

Fuad-Luke, A. (2009). *Design Activism' Teleological Freedoms as a means to transform our habitus*. http://www.mappingsocialdesign.org;

Grates, M. G., Heming, A. C., Vukoman, M., Schabsky, P., & Sorgalla, J. (2019). New Perspectives on User Participation in Technology Design Processes: An Interdisciplinary Approach. *Gerontologist*, *59*(1), 45–57. https://doi.org/10.1093/geront/gny112

Hamilton, R., & Price, L. L. (2019). Consumer journeys: developing consumer-based strategy. *Journal of the Academy of Marketing Science*, *47*(2), 187–191. https://doi.org/10.1007/s11747-019-00636-y

Hienerth, C., Lettl, C., & Keinz, P. (2014). Synergies among producer firms, lead users, and user communities: The case of the LEGO producer-user ecosystem. *Journal of Product Innovation Management*, *31*(4), 848–866. https://doi.org/10.1111/jpim.12127

Higgins, V., & Bryant, M. (2020). Framing Agri-Digital Governance: Industry Stakeholders, Technological Frames and Smart Farming Implementation. *Sociologia Ruralis*, *60*(2), 438–457. https://doi.org/10.1111/soru.12297

Hölzle, K., & Rhinow, H. (2019). The Dilemmas of Design Thinking in Innovation Projects. *Project Management Journal*, *50*(4), 418–430. https://doi.org/10.1177/8756972819853129

Howard, T. (2014). Journey Mapping: A Brief Overview. *Communication Design Quarterly*, *2*(3), 10–13. https://doi.org/10.1145/2644448.2644451

Hoyer, W. D., Chandy, R., Dorotic, M., Krafft, M., & Singh, S. S. (2010). Consumer Cocreation in New Product Development. *Journal of Service Research*, *13*(3), 283–296.

https://doi.org/10.1177/1094670510375604

Kelley, T., & Kelley, D. (2013). *Creative confidence: Unleashing the creative potential within us all. Currency.*

Knight, E., Daymond, J., & Paroutis, S. (2020). Design-Led Strategy: How To Bring Design Thinking into the Art of Strategic Management. *California Management Review*, *62*(2), 30–52. https://doi.org/10.1177/0008125619897594

Kolko, J. (2014). Well-designed: how to use empathy to create products people love. . *Harvard Business Press.*

Kristensson, P. , Gustafsson, A. , & Archer, T. (2004). Harnessing the creative potential among users. *Journal of Product Innovation Management*, *21*(1), 4–14. https://doi.org/10.1111/j.0737-6782.2004.00050.x

Lemon, K. N. , & Verhoef, P. C. (2016). Understanding customer experience throughout the customer journey. *Journal of Marketing*, *80*(6), 69–96. https://doi.org/10.1509/jm.15.0420

Lewrick, M., Link, P., & Leifer, L. (2020). *The Design thinking toolbox*. John Wiley & Sons. https://doi.org/10.15358/9783800657520

Liedtka, J. (2015). Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction. In *Journal of Product Innovation Management* (Vol. 32, Issue 6, pp. 925–938). https://doi.org/10.1111/jpim.12163

Lindblom, J., Lundström, C., Ljung, M., & Jonsson, A. (2017). *Promoting sustainable intensification in precision agriculture: review of decision support systems development and strategies*. *18*, 309–331. https://doi.org/10.1007/s11119-016-9491-4

Malins, J. P. (2011). *Innovation by Design: Using Design Thinking to Support SMEs*. http://openair.rgu.ac.uk

Margolin, V., & Margolin, S. (2002). A “Social Model” of Design: Issues of Practice and Research. In *Source: Design Issues* (Vol. 18, Issue 4). https://doi.org/10.1162/074793602320827406

Meyer, C., & Schwager, A. (2007). *Understanding Customer Experience*. www.gethuman.com

Micheli, P., Wilner, S. J. S., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). Doing Design Thinking: Conceptual Review, Synthesis, and Research Agenda. *Journal of Product Innovation Management*, *36*(2), 124–148. https://doi.org/10.1111/jpim.12466

Moretti, D. M., Baum, C. M., Wustmans, M., & Bröring, S. (2022). Application of journey maps to the development of emergent sustainability-oriented technologies: Lessons for user involvement in agriculture. *Business Strategy and Development*, *5*(3), 209–221. https://doi.org/10.1002/bsd2.192

Nenonen, S. , Rasila, H. , Junnonen, J.-M. , & Kärnä, S. (2008). Customer Journey a method to investigate user experience. *In European Facility Management Conference 10.-11.6.2008, Manchester, UK.*, 45–59.

Olivares U., J. E., & Arévalo G., J. (2022). Aprendizajes en ingeniería de prototipado en centros de investigación de una universidad pública en Bolivia. *I+Diseño. Revista Científico-Académica Internacional de Innovación, Investigación y Desarrollo En Diseño*, *17*, 77–102. https://doi.org/10.24310/idiseno.2022.v17i.15221

Pap, M., Vdović, R., & Baletić, B. (2019). Design Thinking metoda u znanstvenom istraživanju, edukaciji i poslovnoj praksi. *Prostor*, *27*(2 (58)), 334–347. https://doi.org/10.31522/P.27.2(58).12

Plattner, H. (2015). An introduction to design thinking. *Process Guide. Institute of Design at Stanford.*

Poetz, M. K., & Schreier, M. (2012). The value of crowdsourcing: Can users really compete with professionals in generating new product ideas? *Journal of Product Innovation Management*, *29*(2), 245–256. https://doi.org/10.1111/J.1540-5885.2011.00893.X

Ricaldi, Montaño, N. , Durán, A. , & Veizaga, J. (2018). El huerto familiar como estrategia productiva y alimentaria frente al cambio climático. Comunidades de Catachilla y Rancho Nuevo. Municipio Santivañez, Proyecto Resiliencia de los Sistemas productivos y alimentarios locales frente al cambio climático. *Talleres Gráficos Kipus* .

Ricaldi, T. (2023). *LA CO-CONSTRUCCIÓN DE RUTAS DE APRENDIZAJE SOBRE LOS SISTEMAS AGROFORESTALES FAMILIARES EN LAS COMUNIDADES DE CATACHILLA Y RANCHO NUEVO-MUNICIPIO DE SANTIVAÑEZ 1*.

Richardson, A. (2010). Using customer journey maps to improve customer experience. *Harvard Business Review*, *15*(1), 2–5.

Rohracher, H. (2003). The Role of Users in the Social Shaping of Environmental Technologies. *Innovation: The European Journal of Social Science Research*, *16*(2), 177–192. https://doi.org/10.1080/13511610304516

Seidel, V. P., & Fixson, S. K. (2013). *Adopting Design Thinking in Novice Multidisciplinary Teams: The Application and Limits of Design Methods and Reflexive Practices**. https://doi.org/10.1111/jpim.12061

Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal*, *50*, 20–24. https://doi.org/10.5465/amj.2007.24160882

Suci, A., Maryanti, S., Hardi, H., & Sudiar, N. (2022). Embedding Design Thinking Paradigm in a University's Business Assistance to Small Business. *Systemic Practice and Action Research*, *35*(2), 177–201. https://doi.org/10.1007/s11213-021-09565-w

Tatikonda, M. V, & Stock, G. N. (2003). Product Technology Transfer in the Upstream Supply Chain. *Journal of Product Innovation Management*, *20*, 444–467. https://doi.org/10.1111/1540-5885.00042

Trojer, L., Rydhagen, B., & Kjellqvistt, T. (2015). Inclusive innovation processes – experiences from Uganda and Tanzania. *African Journal of Science, Technology, Innovation and Development*, *6*, 425–438. https://doi.org/10.1080/20421338.2014.970437

Von Hippel, E. (2005). Democratizing innovation: The evolving phenomenon of user innovation. *Journal Fr Betriebswirtschaft*, *55*(1), 63–78. https://doi.org/10.1007/s11301-004-0002-8

Von Hippel, E., & Katz, R. (2002). Shifting innovation to users via toolkits. *Management Science*, *48*(7), 821–833. https://doi.org/10.1287/mnsc.48.7.821.2817

Appendices

ANNEX 1. Interview Protocol 1

Santivañez Agroecological Producers/Producers "Eco-Huertos".

Journey Map Application (ACTIVITIES, MOTIVATIONS AND BARRIERS)

Evaluation of the Experience – BEFORE AND DURING THE DEVELOPMENT OF COLLECTIVE GREENHOUSE

STEP 1- PERSON: Choose the end user and share their story with the design team.

1. Who are you?
2. How and where do you live?
3. How old are you approximately?

STEP 2- SCENARIO: Determine the scenario. Describe a Little of the environment where you live, the daily work activities you do, with who you work.

4. What do you do? What are you working on?
5. What do you think of the collective greenhouse?
6. How do you think it will change your life?

STEP 3- TYPICAL TRAJECTORY: Define what happens: **BEFORE, DURING** and AFTER the Experience to ensure that the most important steps are included.

7. What did you feel when you heard that this project was going to be realized?
8. Why do you need the greenhouse for the whole Eco huertos collective that will be located in Catachilla?
9. The greenhouse is already in the process of being built, how do you feel about having year-round production in the greenhouse?
10. What other elements do you think could be incorporated into the greenhouse?

11. What do you think will happen once the Project will be completed?
12. What desired or motivations do you think will arise after the greenhouse is completed?

STEP 4- ACTIONS: Decide which interactions should be allocated where and how.

13. How is your interaction with the university in the development of this project? What is the work you have done on the projects with CESU research center?
14. What is the work you will do in the development of this project?

STEP 5 and STEP 6- THOUGHTS AND EMOTIONS: Complement What the person thinks (step 5) and the emotion they feel (steep 6)

15. What emotions do you feel about the development of the greenhouse?
16. What risks or inconveniences do you identify that could exist during the development of this project? That is, what is the bad thing that could happen to the greenhouse (wind, rain, thunder, the weather)? What do you think will affect the greenhouse?

STEP 7 and STEP 8- OPPORTUNITIES AND AREAS OF RESPONSIBILITY: Define the possible areas for improvement (step 7) and the persons responsible for the action/process within the organization (step 8)

17. Regarding internal organization, how are you as an "Ecohuerto collective" going to organize yourselves with the work in the greenhouse?
18. And finally, What opportunities (regarding production, organization, technology and learning) do you think will arise with the greenhouse?

ANNEX 2. Interview Protocol 2

Santivañez Agroecological Producers/Producers "Eco-Huertos".

Journey Map Application (ACTIVITIES, MOTIVATIONS AND BARRIERS)

Evaluation of the Experience - AFTER IMPLEMENTING THE COLLECTIVE GREENHOUSE

STEP 2- SCENARIO: Determine the Scenario. Describe a little of the environment where you live, the daily work activities you perform, with whom you work.

1. At the end of this project, what impressions do you have of the collective greenhouse, does it meet the expectations you had? (Productive capacity, pest control, environmental difficulties, water use and organizational ease).

STEP 3- TYPICAL PATHWAY: Define what happens BEFORE, DURING and **AFTER** the experience to make sure that the most important steps are included.

2. What has been the degree of involvement in the greenhouse construction process (e.g., adaptation of new organic production techniques)?
3. What main results did you find from the shared use of the greenhouse (e.g. increased production)?
4. What important elements were they able to incorporate in the greenhouse to improve its capacity and efficiency, and which ones were left pending (e.g. drip irrigation system)?
5. What desires or motivations arose after completing the installation of the greenhouse (e.g., to replicate elements of this experience in their own space)?

STEP 4- ACTIONS: Decide what interactions should be assigned where and how.

6. What are the most relevant activities carried out by the collective for the preparation and during the implementation of the greenhouse? How was the coordination with the

university in the development of this project, do you suggest improvements?

STEP 5 and STEP 6- THOUGHTS AND EMOTIONS: Complement what the person thinks (Step 5) and the emotion they feel (Step 6).

7. What emotions do they feel now that they have a collective greenhouse?
8. What risks or disadvantages do they identify now that they have the greenhouse? That is, what aspects should we take care of to keep the greenhouse functioning well (weather, wind, water, technical, structural, and organizational aspects of care and production)?

STEP 7 and STEP 8- OPPORTUNITIES AND AREAS OF RESPONSIBILITY: Define the possible areas of improvement (Step 7) and the people responsible for the action/process within the organization (Step 8).

9. Regarding internal organization, how did you as a collective organize yourselves in order to carry out the care and maintenance of the greenhouse (e.g. space distribution, irrigation, weeding, planting, harvesting, pests)?
10. Currently, what is being produced mainly in the greenhouse?
11. And finally, what other opportunities (regarding production, organization, technology, and learning) do you think will arise with the greenhouse? Do you want this experience to be replicated within the collective or in other areas of the municipality?

About the author

Jazmin has a background in design strategies, prototyping and social innovation. Her research is focused on theoretical and practical application of design approaches like design thinking for development of production machines for small and medium sized enterprises within cluster initiatives facilitated by a university in Bolivia. Her research includes experiences of design projects of prototypes and machines developed for SMEs of cluster initiatives. The first insights of this research allowed the identification of strategies and critical factors that may facilitate the application of Design Thinking for product development within these resource-constrained SME contexts.

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