Polytechnic Institute of Coimbra

Institute of Accounting and Administration of Coimbra

Innovation, Creativity and New Product Development: A Human-Centred Design Case Study

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Project

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Project carried out in the Master of Business Management with the Advisor: Professor Doctor João Paulo de Moura Martins Coelho Marques

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I declare to be the author of this project, which is an original and unpublished work that has never been submitted to another institution of higher education to obtain an academic degree or other qualification. I also certify that all quotations are properly identified and that I am aware that plagiarism constitutes a serious lack of ethics, which could lead to the cancellation of this project.

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ABSTRACT

Innovation as been changing through the years and companies are continuously seeking for enhanced processes to achieve competitive advantage. Innovation is now seen as an open and collaborative process with the entering of different players in the ecosystem. Universities are relevant candidates to change innovation landscape and contribute to the reality of a learning economy.

The present work explores a university-industry collaboration based on a case study of an innovation project under the ME310 program. Porto Design Factory (P.Porto) and IKEA Industry joined forces to tackle a problem using the Human-Centred Design (HCD) approach. The case study methodology provides an understanding the outcomes that revealed the potential of the HCD to solve a technical problem while enhancing the customer experience. Also, it's possible to recognize the benefits that each institution had by collaborating. Research, prototypes and comprehensive documentation with all the knowledge generated through the process, were some of the results that contributed to the company's innovation effort. PDF also benefited by providing differentiating learning conditions and employment opportunities to its students.

The outcomes show that companies do benefit from building interfaces with external partners and that universities are relevant players in the innovation ecosystem satisfying its third mission.

Further investigation may look for the level of implementation of the concepts coming from this kind of partnerships as well as it impacts in company's culture and work process in the long term.

Key-words: Innovation, New Product Development, University-Industry cooperation, Human-Centred Design

RESUMO

A visão e a compreensão da inovação têm mudado ao longo do tempo e as empresas procuram continuamente adaptar-se de forma a obterem vantagem competitiva. Hoje, a inovação é aberta e colaborativa, o que permite a entrada de outros stakeholders no ecossistema. As Universidades estão cada vez mais aptas a responder aos desafios da Indústria, na era da Economia Baseada no Conhecimento e desejam contribuir para a sociedade com o valor criado pelas suas atividades.

Este trabalho abordara temática da inovação e da relação universidade-indústria através de um caso de estudo baseado no programa ME310. Neste projeto, Porto Design Factory (P.Porto) e IKEA Industry juntaram-se para resolver um problema através da abordagem Human-Centred Design. Através do estudo de caso, é possível evidenciar o potencial desta abordagem para resolver problemas técnicas enquanto se melhora a experiência do cliente. É possível, também, perceber os benefícios que cada instituição alcançou através desta colaboração. Os resultados da pesquisa, os protótipos e a documentação com todo o conhecimento gerado durante o projeto, são alguns dos outputs relevantes para a empresa. A Porto Design Factory também obteve vantagens em relação à promoção de melhores condições de ensino e relativamente às ofertas de emprego proporcionadas aos estudantes.

Os resultados do projeto demonstraram o potencial da criação de interfaces com o ambiente externo às empresas e a capacidade das instituições de ensino superior de contribuírem para o ecossistema de inovação satisfazendo a sua terceira missão.

No futuro, a investigação poderá incidir mais profundamente no nível de implementação dos resultados deste tipo de projetos como os conceitos explorados e provas de conceito, bem como o impacto na cultura da empresa e seus colaboradores, a longo prazo.

Palavras-Chave: Inovação, Desenvolvimento de Novos Produtos, Colaboração Universidade-Indústria, Human-Centred Design

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List of Abbreviations

CEP – Critical Experience Prototype

CFP – Critical Function Prototype

CIM – Cyclic Innovation Model

EPO – European Patent Office

FY – Financial Year

HCD – Human-centred Design

HEI – Higher Education Institution

ME310 – Innovation course previously called “Mechanical Engineering 310”

OECD – Organisation for Economic Co-operation and Development

PDF – Porto Design Factory

PRI – Private Research Institute

R&D – Research and Development

UIC – University-Industry Collaborations

VCW – Value Creation Wheel

INTRODUCTION

Innovation has been understood as a driver for businesses to seek long-term successful performance (Tushman & O'Reilly, 2002). Despite it being a common topic among industry leaders and academics, innovation has a past of constant evolution that led to today's vision of innovation as a process that allows organisations to adapt to new situations and capitalize its knowledge (Lundvall & Nielson, 2007). Creativity is an important part of innovation (Amabile, Conti, Coon, Lazenby & Herron, 1996). Both incremental and radical thinking need to be approached with a mechanism that provides improvements and breakthroughs worth of satisfying old and new customers and be fully integrated in the firm's strategy.

Companies were responsible for most of the innovative endeavours, but it all changed when innovation started to be a co-creative and collaborative process. Cross-organisation projects started to be the benchmark and it is believed that this approach may lead to knowledge generation and transfer that otherwise, with a closed process, wouldn't be possible. Higher education institutions started to be crucial players in the innovation ecosystem (OECD, 2019), as suppliers of knowledge, skilled workers and research facilities providers.

This work aims at understanding the evolution of corporate innovation throughout the years, culminating in what characterizes innovation today. The general goal will be to study innovation processes and methodologies, considering the Human-Centred Design approach in the context of university-industry collaboration.

The first chapter provides a theoretical framework regarding the evolution of the innovation models (from the linear thinking to the interactive and customer-centred approach), innovation processes (stage-gate model, VCW, Lean Startup and Human-Centred Design), followed by the role of creativity in innovation and ending with the rising of University-Industry collaborations.

After the first approach to the scope of this work, the second chapter elaborates on the methodological approach, the case study. As a scientific method that allows a deep understanding of a given reality, the case study provides critical insights based, in its majority, in qualitative data. It will provide the necessary information to explore and describe the ME310 innovation project in terms of the motivations that led to the partnership and its outcomes.

Lastly, the third chapter will be composed by the case study itself. It will focus in explaining the reality of the IKEA Group and the IKEA Industry in particular, as the biggest wood and wood-based furniture manufacturer in the world. IKEA is known as a brand that has design-driven products and a disruptive business model. IKEA also invests deeply in innovation and in partnerships with external organisations to make sure that the company is equipped with the state-of-the art knowledge and truly understands global trends.

At the end of this work it is expected to have a broad understanding of what is innovation and how it is done in practice nowadays. The example of the case should bring thoughtful insights regarding the structure of external partnerships and its potential for the development of new products and knowledge generation.

CHAPTER 1. THEORETICAL FRAMEWORK

1. Innovation and New Product Development

1.1. Concept evolution

Innovation has been an important topic throughout the years with considerable economic, social, political and technological impact. The early days of innovation studies had the economist Joseph Schumpeter (1934) has a key element in finding the importance that new product development had in the economic growth. His vision postulated that market disruption and competitiveness would be greater when business adopted innovation-driven activities rather than by simply target the price as a differentiable asset. The general premise was that innovation was strongly connected with companies' resources and capabilities to manage its internal efforts towards the transformation of knowledge into new products.

Many authors have been defining innovation and it has been changing according to the economic, social and historical moments.

The crucial characteristic of an innovation is creating something new that brings value to the economy. From the entrepreneurship perspective, innovation is seen as the tool for the entrepreneur to develop new products and services (Drucker, 1985). Schumpeter called it the "Creative Destruction" referring to the impact that new solutions (products, services) have in the previous artefacts that are replaced by the innovative ones. This means that there has to be some level of disruption with the past with the diffusion of innovation that opens up new ways of solving existing problems. Following that line of thought, innovation is oftentimes perceived as the first time a new product, service or technology is introduced in the market (Teece, 1986). The linear innovation models of the past corroborate this vision of something new that is created and is further develop until its introduction in the market. But the understanding of the results of innovation and the "market" have changed.

As shown in OECD (2005) the innovative outcomes are not limited to services or products but are divided in four groups: Product, Process, Organizational and Marketing, which brings a broader vision of innovation and the variety of outcomes that may derive from the process. Therefore, the "market" might not only be where the customers are but also where the workers are. Solutions resulting from assessing the internal environment and processes of the firm, may lead to innovations to be implemented within the organization.

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Innovation as an outcome is *"a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)*" (OECD, 2018).

Since the 50's that many are studying the occurrence of innovation and trying to understand how to achieve the success in such a complex and uncertain activity. The goal of understanding the process is to provide competitive advantage to the ones that know the steps towards innovation and practice it regularly and objectively. As an ever-learning process, innovation requires resilience to deal with failures and setbacks and the key for a long term successful innovative performance is to make it systematic. Organizations' leaders and workers need to bear in mind the importance of having the constant awareness for opportunities to innovate and need to feel empowered to make critical decisions related to problem-solving initiatives. This makes it clear that innovation must not be an isolated and sporadic effort, but rather an activity embedded within the company, as a management process. Trott (2012) affirms that

"*Innovation is the management of all the activities involved in the process of idea generation, technology development, manufacturing and marketing of a new (or improved) product or manufacturing process or equipment*".

This vision brings to innovation a global and dynamic role inside of the organizations. As an internal activity, it is strongly linked to the company's culture and the co-worker's motivation to keep the mentality of developing new solutions for the problems encountered (Arnold & Thuriaux, 1997; Tidd & Bessant, 2018). It is also complemented by the principles of a learning organization (Lundvall & Nielson, 2007), if the firm is a well "oiled" innovative machine, all individuals and departments must be aligned to be able to acquire and apply knowledge into solutions.

In the past, companies and governments found that R&D activities were a great source of innovation. Proof of that were the advances in radar, aerospace and weapons technologies promoted by the scientific efforts during the Second World War, that led to an increment of public investment in this area (Harrod, 1949; Domar,1946).

Different perspectives on corporate innovation kept occurring with showing new approaches and iterating on the previous concepts. Despite science and technology being strongly connected to innovation, at some point it was no longer seen as the best and unique source of insights to the innovation process. Marketing knowledge and customer-centred approaches were increasingly relevant to the development of new solutions (Rothwell, 1994).

Further studies brought a more structured and complex understanding of the meaning and types of innovation. Industries were practicing innovation in different ways according to its core business, the technology's state-of-the-art and market opportunities. Some companies concentrated their innovative efforts in doing "incremental" changes to previous products to provide new features to the current users, while others were capable of developing one of a kind "radical" product that would open new market opportunities to get new customers while conferring a competitive advantage within the activity sector (Freeman & Soete, 1997; Christensen, 2003).

Economic, social and technological changes through the years brought an evolutive vision on business and innovation. A global economy took place with the continuous development of transportation and communication technologies that have been impacting industry by allowing foreign investment, world-wide sourcing and cooperation between firms (Lundvall & Borrás, 1997). Companies started to exchange and acquire new knowledge faster and easier which contributed to the openness of the innovation processes themselves. External collaborations, co-creation projects, inclusion of stakeholders in the innovation process, followed the paradigm of Open Innovation that states the importance of linkages and information flow to the firm's success (Chesbrough, 2003a). A successful innovation process allows companies to be aware of the market needs and promotes a continuous learning to incorporate new insights into the process along the way (Hamel & Prahalad, 1994).

1.1.1. Innovation is a Learning Process

Firms are "machines" that transform economically useful knowledge into value for its customers. This knowledge is one of the most important assets that support all the activities of the organization and it has a key role in innovation. In fact, for an organization to be innovative it must be intelligent and creative (Glynn, 1996; Woodman, Sawyer & Griffin 1993), capable of learning effectively (Senge, 1990; Argyris & Schon, 1978), and able to create new knowledge (Nonaka, 1994). Knowledge is intrinsically embedded in the way innovation is done that, according to Pavitt (2005), firms must be able to produce knowledge, transform it into artefacts and continuously be aware of market needs and demands to iterate on the innovations produced. This process may be understood as a way of defining new problems and creating new knowledge to solve them.

Managing knowledge inside of an organization can be a hard task and the use of rules, procedures, routines and shared norms may be some of ways to transform individual knowledge into collective or organizational knowledge. This knowledge presents itself in different manners as being tacit or codified. Tacit knowledge is the one that is implicit in the skills and competences of individuals or organization, that is not possible to separate from the firm, it's also known as know-how. The mediation of this knowledge is only possible through training and education or the purchasing of it as a service. Coded knowledge, on the other hand, is when information turns explicit, it has the benefit of being easily accessible to the user of the knowledge but it requires a balance to not being too technical or utilizing jargon, in order to keep understandable by others (Pavitt, 2005).

This is the basis for knowledge-intensive industries that raised the demand for skilled and educated workers dedicated to R&D activities that would generate new knowledge to than be applied into new product development. The technological evolution and the globalisation of businesses are the source of a drastic and rapid change in competition, in markets, in the general way of doing business. Having the skills and competences inside the firm and support on them to provide the long-term responsiveness to upcoming challenges is not fitted to today's business era. As knowledge is continuously changing and being created, there's a great demand for companies to be able to adapt fast and, therefore, to learn fast. That's the rise of the Learning Economy proposed by Lundvall & Johnsson (1994). Learning is now a critical success factor that firms need to balance between the science-based learning, the systematic process of researching, creating knowledge that is often codified, and the experience-based learning, that's learning by doing, by using and by interacting, the tacit knowledge embodied in people and embedded in the organization.

Changes in firms' processes, rules and structure are crucial to the adaptation to this ever-changing environment led by fierce competitors and the continuous creation of new knowledge and new ways to apply it. Lundvall & Nielson (2007) defined the principles for a successful learning organization that translate effectively the changes organizations must do to be active players in the learning economy:

1. Promote interaction between different specialized departments within the company, job circulation and interdivisional teams are ways of doing it;

2. Reduce layers in the organization to speed up communication and delegate responsibility towards the level where action is required;
3. Open the organization to the external world at all layers of hierarchy.

Learning demand is the call for agility, bureaucracy reduction, openness, collaboration and empowerment of workers. This is a type of firm very different from the Taylorist approach or from the siloed firms that only focus on the inside and see the external environment as the unknown or as competition. It's crucial that organizations have the "absorptive capacity" to recognize the value of new, external information, to apply it for commercial purposes (Cohen & Levinthal, 1990).

That vision matches the one from Caraça, Lundvall & Mendonça (2009) that stated the importance of being interactive and open to the acquisition of knowledge outside of the firm. Innovation is a vehicle of knowledge that comes from a large variety of sources and promotes the application of such knowledge into solutions or provides insights to feed back the process.

1.1.2. Innovation is Open and Network-based

The analysis of innovation of the last two topics unveiled the transformation of the solid boundaries of firms into semi-permeable ones in order to allow the transition of knowledge in and out of the organization. External sources of innovation have been considered important inputs to the firms' innovation process (von Hippel, 1988) and the need for organizations to have "doors" or interfaces to objectively collect external information to make it economically useful (Caraça et al, 2009). External factors may influence firm's innovation activities, capabilities and outcomes and they may come from customers, competitors and suppliers, the labour market, legal and regulatory affairs and the competitive and economic conditions (OECD, 2018).

Network-based innovation has been studied for some time (Powell, 1990; Rosenbloom & Spencer, 1996) and it is possible to establish a strong linkage between partnered innovation activities and its successful outcomes. Essentially, interorganizational relationships allow the partners to access new markets, spread risks and/or share early stage R&D costs (Mowery, 1988). This may take the form of research consortia, joint ventures, strategic alliances or subcontracting. Specially in the 90's analysts noticed an increase of the reliance on external R&D sources such as universities, consortia, government labs, and collaboration between domestic and foreign competitors (Mowery, 1999).

Innovation took also a national, regional and sectoral perspective as it was considered a core activity for the economic development of nations. Political, corporate and social areas were streamlined with this vision and structures like National and Regional Innovation Systems were putted into practice worldwide. The systems view of innovation stresses the importance of the external environment by conceptualizing the innovation activities of firms as embedded in political, social organizational and economic systems (Lundvall, 1992; Nelson, 1993; Edquist, 2005).

More recently, Chesbrough (2003a) theorized about the changes happening in society, the technological evolution and what was occurring is business and explored the concept of Open Innovation. The shift in the way companies generate new ideas and bring them to the market removed internal R&D from the invaluable strategic asset that was once. The closed innovation paradigm made companies own and control all the innovation process making the exposed to limits of their knowledge and resources. But the new paradigm defends that managing innovation is about opening the innovation process and combine technologies developed internally and externally to create business value (Chesbrough 2003a, 2003b).

Open innovation is *"the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand markets for external use of innovation, respectively",* for that matter both internal and external ideas, resources and market paths are relevant for the process (Chesbrough, Vanhaverbeke & West, 2006).

Some ways to objectively practice open innovation according to Enkel, Kausch & Gosman (2007):

- customer and supplier integration;
- listening posts as innovation clusters;
- applying innovation across industries;
- buying intellectual property;
- investing in global knowledge creation.

Open innovation in practice increases the complexity of the innovation process as more players enter the game and it represents and challenge for the managers. Also, balancing the openness is an issue that requires some ability as it must be a "continuum between high and low degree of openness" (Chesbrough, 2003b) through the process. The company must learn how to balance the competing goals of "the exploitation of old certainties" and "the exploration of new opportunities" (March, 1991) which means managing the external activities related to innovation and the internal activities that make the core of the business (Fredberg, Elmquist & Ollila, 2008).

Despite being a widely accepted model, Open Innovation is not a completely disruptive paradigm as perceived by Marques (2014) and Trott & Hartman (2009). In 1969, Allen and Cowen had stated the importance of permeable structures inside firms that would be an interface between R&D employees and external teams of scientists. Also, partnerships among companies have been in place for a long time (Grow & Nath, 1990). In order to fulfil firms' needs of developing new products and do R&D activities, cross-organisational partnerships allowed each intervenient to share costs and acquire competitive advantages.

The Open Innovation model is also understood by some academics that it brings back the old linear view of innovation which has been conceptually failing to explain today's innovation processes (Trott & Hartman, 2009).

Chesbrough model has several elements that may be questioned but the fact that it has been implemented in many well-known companies (Hacievliyagil, Auger, Maisonneuve & Hartmann, 2008), may constitute an opportunity to further develop the concept and turn it more suitable for today's reality.

1.2 Innovation Models Overview

Innovation has been a topic hardly consensual and rather evolutive in terms of its definition, semantics and process. Also, the way to achieve it was for some time an incognita and oftentimes randomness was thought as the key factor of new product development. One way to understand the evolution of corporate innovation it's through the several models developed by thoughtful authors across the years. By analysing them it's possible to understand the corporate, economic, social and political situation of each decade and allows a holistic and comprehensive view of innovation evolution. The next considerations about the evolution of the innovation processes are easily overlapped with the brief introduction given previously.

"Innovation is inherently uncertain, somewhat disorderly, involves some of the most complex systems known, and may consist of changes of many sorts at many different places within the innovating organization"

Kline & Rosenberg, 1986

Researchers and industry leaders from the 1950's and before had difficulty in defining how new product development happened. It was believed that it had a random factor attached to it and it was not organized and systematic. The words of Prof. Kline and Prof. Rosenberg on the National Symposium on Innovation in 1985 reveal that, in fact, innovation is complex and involves risk.

Innovation is a driver for the acquisition of competitive advantage and for that reason it must be organically practiced inside companies and they must be prepared to adapt quickly to the vast challenges coming from the clients, the competitors, the technological evolution and the scientific breakthroughs. In order to become a systematic and organized phenomenon it must have a way to be done - a process.

An innovation process is an organized path towards the solution of problems, focusing on systemic and persevering operations combining knowledge, abilities and the behaviour of an individual (Pärttö & Saariluoma, 2012; Verganti & Öberg, 2013). It comprises the activities and capabilities needed to create something new from the conception until its launch in the market. The comprehension of the development of the process phases and its relations is an important element to understand the way innovation is done (Gordon, Tarafdar, Cook, Maksimoski & Rogowitz, 2008). The activities are structured and standardized to allow the identification and analysis of an opportunity, the generation and selection of ideas and further development until the introduction in the market (Hacklin, Inganas, Marxt & Pluss 2009; Koen et al., 2001).

The innovation process is systemic and takes in consideration all the dimensions of the business which means including all the developed processes of the company to generate and deliver value (Sawhney, Wolcott & Arroniz, 2011). Innovation models and processes have been extensively studied and developed both in industry and university. Advances in technology, new scientific discoveries and the increasing importance of R&D for the long-term competitiveness of companies, were important aspects for the determination of the timeline of innovation processes.

After World War II there was an important economic growth, markets were developed and the competitiveness raised and from that moment on innovation was a driver for efficiency and maintenance of competitive advantage (Rothwell, 1994). Since the 1950's researchers and industry leaders focused their efforts in understanding how innovation occurred and tried to establish general models that oftentimes were adapted to a company's situation.

1.2.1. Linear Innovation Models

Until the mid-1960's the economic growth was due to rapid industrial expansion and the raising of new technologies that created new opportunities. It was believed that the more a company concentrated in R&D more successful would be its new products. That vision was stated in the Linear Model (Figure 1).

Fig. 1 - Linear Innovation Model (Rothwell, 1994)

These models are also called Technology Push Models, this creates the evidence of the linkage between the R&D activities and the success of its outputs as products to be introduced in the market. These models go only in one direction from scientific inputs, to the applied investigation that will culminate in a tangible artefact that will go into production, will be marketed and sold.

At this time scientific outcomes were thought as the only source of inputs to the innovation process. Internal capabilities to fulfil the companies needs in term of understanding and applying the state-of-the-art technologies were considered extremely important. This approach to new product development increased the demand for technical knowledge as the new developments were relying more and more is engineers and scientists.

The extreme focus in the scientific breakthroughs as the unique source of innovation was target of several criticisms raised by Freeman (1977), for example, that confirmed - through the study of other authors about the inputs and outputs of R&D systems - that the outcomes of these activities were strongly linked to feedback inputs. Supported by the work of Jewkes, Freeman also suggests that radical inventions oftentimes come from outside of the R&D laboratory and, although its importance is undeniable, but sometimes is not essential.

Also, Caraça, et al. (2009) confirm the importance of R&D activities but advocate that its positioning in the innovation process is not necessarily in the beginning.

From mid-1960's to the 70's, a new approach was created, and it brought a new perspective about the role of the client and its needs to the development of business (Figure 2). It was still present the linear approach to innovation, but the starting point was no longer the scientific breakthroughs but the market demands, needs and wishes.

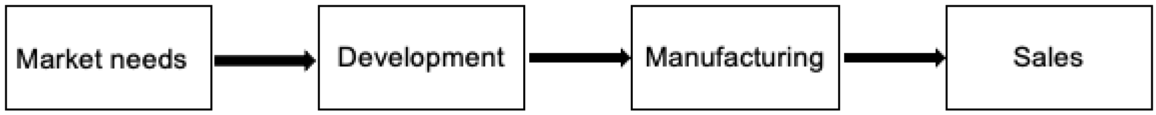

Fig. 2 - Market Pull Innovation Model (Rothwell, 1994)

Contrary to the Technology Push Models, the new paradigm was a Market Pull approach to the new product development which meant the source of inspiration and ideas in this kind of process come from the consumers. This was due to the increasing importance of marketing and it was believed that the market acceptance of a new product would be higher if it answered to non-solved problem.

1.2.2. Third Generation Innovation Model

The 1970's and 80's brought a more structured thinking about innovation. At this point markets were challenging, and companies needed to adopt consolidation and rationalization strategies. The innovation process densified and incorporated the learnings of previous approaches giving birth to the third-generation models or coupling models.

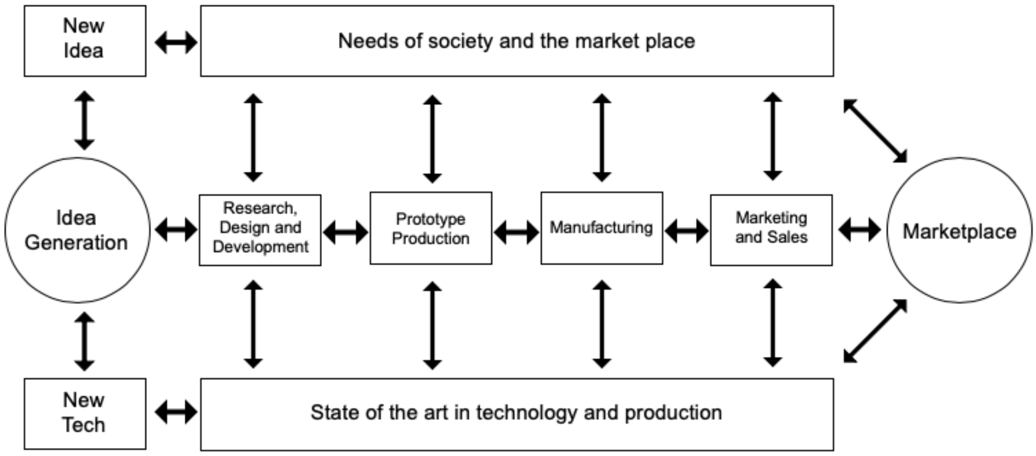

Fig. 3 - Third Generation Innovation Model (Rothwell, 1994)

The third generation innovation model (Figure 3) is structured considering both markets demands and the technological capabilities of the firm in order to have a more sustained innovation, those two aspects follow and interact constantly with the main course of the process. It is denoted more interactions between the well-defined phases which is an important iteration from the previous models.

The linear thinking was yet the paradigm and even today it's present in some initiatives of policymakers, universities and business leaders, determining the funding of innovation, for example (Caraça et al., 2009).

Although linear innovation models were representing the reality of the times when they were developed, they soon became insufficient to explain the complexity of the innovation activities. The deeper study of linear models uncovered some inconsistencies highlighted by Hobday (2005): The sequence of the innovation phases was poorly validated; also, the constant learning happening throughout the process and the outcomes of collaborations between actors in later phases would frequently have implications in early phases and that was not stated in the model; The model didn't refer the frequent collaborations between departments inside the company; There is no strong evidence that validates the phases in such models; The wider environment of the company is not considered as a source of inputs to the process; Finally, the models in simplistic in explaining the innovation that an unorganized and chaotic process.

The evolution of innovation models highlighted incremental but very important changes between the different iterations. The primary Technology Push approach promoting R&D as the main source of innovative insights was proved wrong and drastically changed to a Market Demand model that focused on perceiving the customer needs and wants to ignite the development of new products. Also, this was a short vision on the complex multi sourced innovation process but brought important learnings about the role of technological knowledge from one side and market research from the other. All of that resulted in an incomplete vision of the whole process and suffered important criticisms about the lack of feedback loops and the incorporation of critical strategic alliances between organizations.

1.2.3. Chain-Linked Model

The maturity of the research about corporate innovation led to a more robust but flexible model proposed by professors Kline and Rosenberg (1986) from Stanford University (Figure 4).

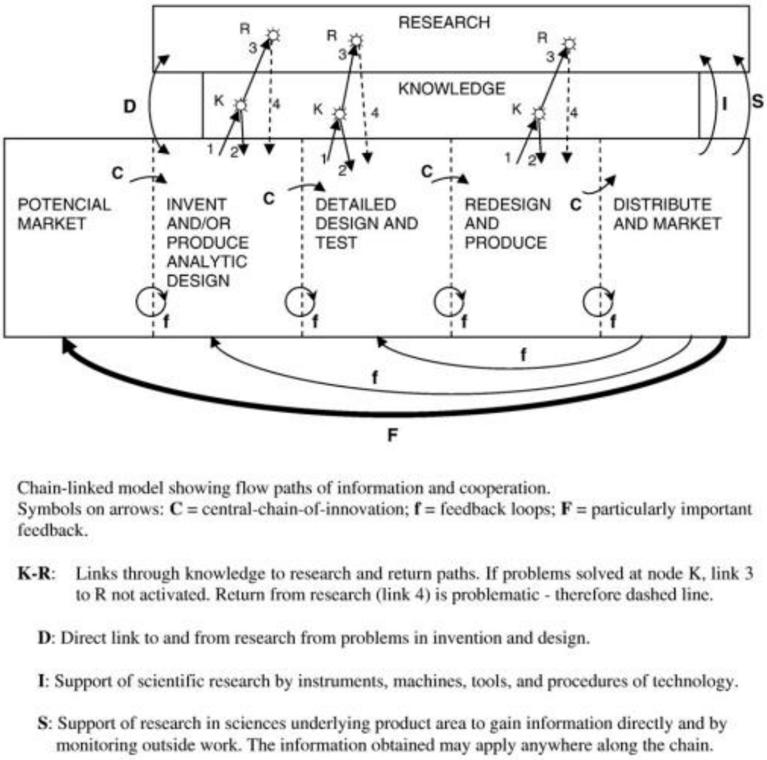

Fig. 4 - Chain-linked Model (Kline & Rosenberg, 1986)

The premise of the Chain-Linked model was stated in the author's own words “innovation is neither smooth nor linear, nor often well behaved”. This makes clear that innovation is a complex process and cannot be predicted, therefore it must be open enough to allow the incorporation of learnings through the process. It gives a sense of continuous innovation, not a static approach from scientific insight to sales that was once. Also states that innovation starts with the finding of an opportunity or market potential at the new product might come from a scientific breakthrough applied to the found opportunity or might promote new scientific and technological findings itself. That was an important change in the paradigm, not only innovation could be enhanced by previous scientific and technological knowledge but also the market research and the innovation activities could lead to the creation of new scientific endeavours.

The Chain-Linked Model was the starting point for a new vision of the corporate innovation as a fluid and dynamic process that must be prepared to incorporate old and new knowledge from the technological and the market perspectives to enrich the outcome.

Today, modern businesses need to be even more prepared to answer to market and scientific challenges as the social and technological environments are constantly evolving and requiring adaptability competencies from all organizations. Currently, companies that are eager to stay competitive and have high performances, work in a wider context and in diversified environment.

1.2.4. Multi-Channel Interactive Learning Model

Iterating in the Chain-Linked Model, Caraça et al. (2009) created the Multi-channel Interactive Learning Model. It is an adaptation to the current reality of the learning economy. The authors consider that, although the previous model was an important landmark in the innovation process evolution, it was needed a modern remodelling that would take in consideration a wide variety and complex variables that companies face nowadays. The Multi-channel model gives an organizational perspective that was lacking before. It explicitly acknowledges that companies must deal with a wider institutional setting (micro and macro environments) like socio-political subsystems of society that may influence and are influenced by the innovation produced in companies that are the key element in the model as the principal promoters of innovation.

With this perspective, well succeeded innovations come from the integration of commercial, strategic and technical competencies, that might be already developed inside the company or might be acquired outside resulting in a chain of interactions. This leads to a systemic view of innovation not only focusing in internal technical capabilities or the capacity to learn the market, but also the importance of considering all institutions and players as influencers of the innovation process and sources of knowledge. The openness of the company to absorb the external environment is clearly present in the model in the “Interfaces” that act like doors that are open to commute knowledge in and out of the organization.

The Multi-Channel Learning Model (Figure 5) frames a vision of innovation adapted to the XXI world and it states the complexity of innovation. It also gives a holistic perspective as it frames innovation politically, economically and socially.

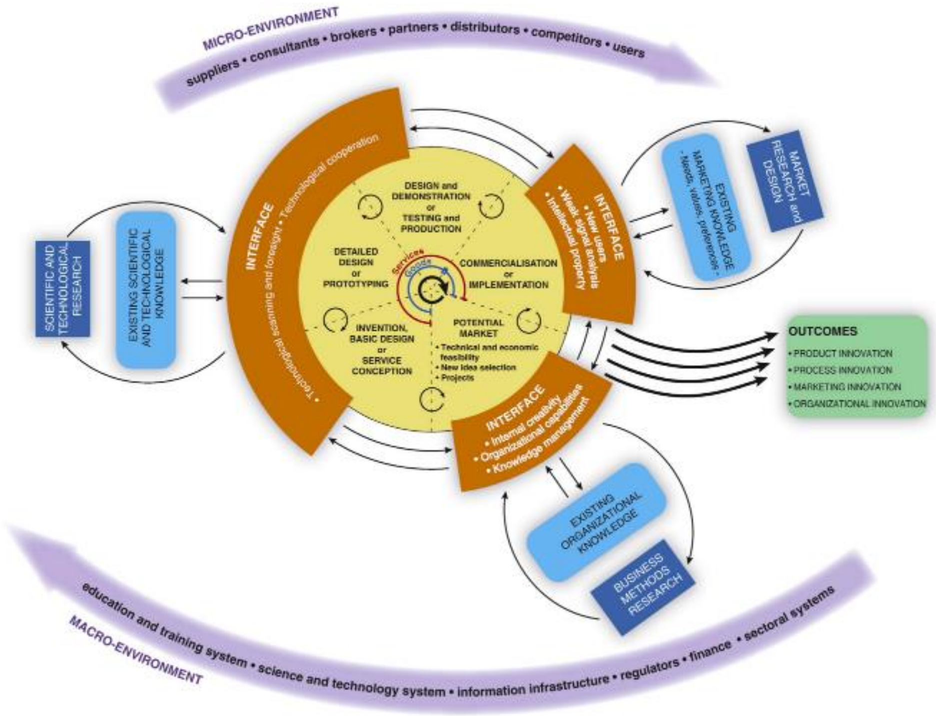

Fig. 5 - The multi-channel learning model (Caraça et al., 2009)

The transition to a non-linear approach to innovation helped to let go the existing vision of causation in such an unpredictable and uncertain process. The importance of including feedback loops (Kline & Rosenberg, 1986) and the need to open the innovation activities to other players (Chesbrough, 2003a), brought a modern model of innovation that represents the complexity and the interconnectivity between areas of knowledge and stakeholders called Cyclic Innovation Model or CIM.

1.2.5.Cyclic Innovation Model

The model developed by Berkhout, Hartmann & Trott (2010) (Figure 6), begins with the recognition that innovation occurs through the interaction of the science base, technological development and the needs of the market. Meaning that, the interaction of these activities translates into the firm's ability to innovate.

Innovation has been described as an information-creation process that arises out of social interaction. Therefore, a successful innovation processes can be thought of as a complex set of communication paths that promote and facilitate knowledge transfer which must include internal and external linkages. These interactions are opportunities for exchanging and sharing thoughts, potential ideas and views.

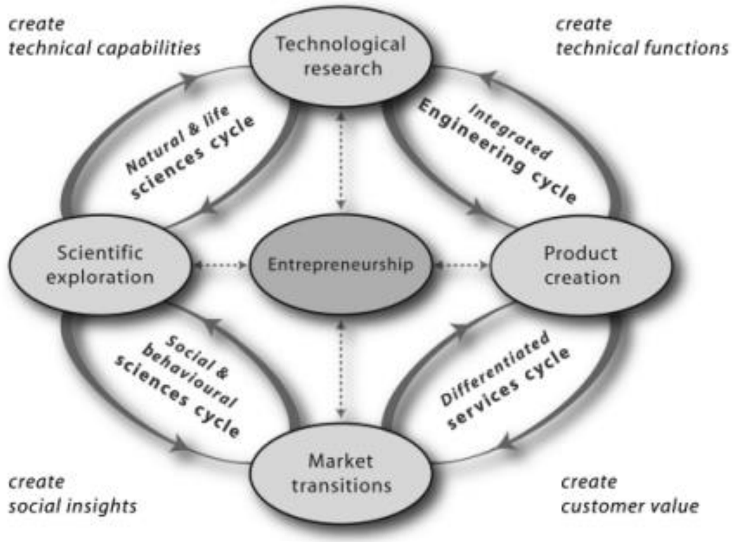

Fig. 6 - Cyclic Innovation Model (Berkhout *et al*., 2010

"The cyclic innovation model (CIM) presents the processes in innovation by a circle of change. Changes in science (left) and industry (right), and changes in technology (top) and markets (bottom) are cyclically interconnected. Nodes function as roundabouts. Entrepreneurs function as circle captains."

The understanding of those four different "worlds" and its dynamics is crucial to put in place an effective process:

1) Scientific Exploration - Technological Research: is the linkage that allows the interaction between the development of new technologies occurring in the natural and life sciences cycle and the development of new technological capabilities by an interdisciplinary team of scientists;

2) Technological Research - Product Creation: is the cyclical interaction that allows the development of new products from a cross-technology process where technological capabilities are needed to design and prototype;

3) Scientific Exploration - Market Transitions: is the process by which the development of new insights into emerging changes in demand, is done. Behavioural and social scientists' foresights shift in societal needs and emotions as well as changes in trade conditions and regulations;

4) Market Transition - Product Creation: process by which product-service combinations occur to serve the changing society and brings value to it.

The overall vision of the model is that behavioural sciences and engineering as well as natural sciences and markets are brought together in the system of synergetic processes with four principal nodes. The changes coming from these interactions constitute opportunities, where entrepreneurship plays a key role managing it transforming them into new business. CIM represents a modern socio-technical framework that allows the understanding of innovation as an iterative and interconnected activity that expects synergetic alliances and internal alignment to perceive business opportunities to generate new value.

The innovation models discussed before are conceptual and visual representations of the historical findings regarding the economic, social and political understandings of innovation through the years and across industries. Some stated the initial thoughts of an understudied phenomenon in the beginning and mid of the last century, others represent a modern frame that attempts to explain the complexity of the current business conditions regarding innovation. They provide a general and holistic comprehension of firms' innovation interactions and its internal and external arrangements towards success.

2. Innovation in Practice

Since decades ago, but with special emphasis in the last years, many processes, methodologies and tools were developed to fill the gap between the theoretical understanding of innovation and the day-to-day activities that lead to innovation. They represent different approaches to managing innovation and problem-solving but all of them attempt to downgrade the complexity of innovation to tangible and easily comprehensible elements envisioning a smooth implementation of such activities.

Table 1 shows some of the most relevant approaches that have been adopted by established firms and start-up companies to develop their innovative solutions. Some of them have overlapping stages, steps or subprocesses, which means there are some common points when doing innovation, but in general they represent a different focus. The scope may vary being narrower or broader when compared to the whole process of innovation, meaning some may actively target one part of it or several. Also, the comprehension of such approaches is beyond the visual representation of its steps/stages, but other tacit elements like practices, experiences, mindsets and company cultures, for example, must be considered to fully understand each process.

The following section aims at having the deeper exploration of some of the most relevant innovation processes and methodologies used globally.

2.1. Innovation Processes

2.1.1. Stage-Gate Model

The Stage-Gate Model was based on the research work done by Cooper & Kleinschimdt (1986), by studying many companies they were able to understand that there were common steps among the processes used by each company when doing innovation (Figure 7). This translated to a new product development process that consists of predetermined set of stages and a decision point between each stage, called gate. The general representation of the authors shows a process ranging from the "Idea" to the "Post-implementation Review", but the goal is the adaptation to each firm's reality and context which may represent, generally, a model from 4 to 7 stages with specific denominations and criteria.

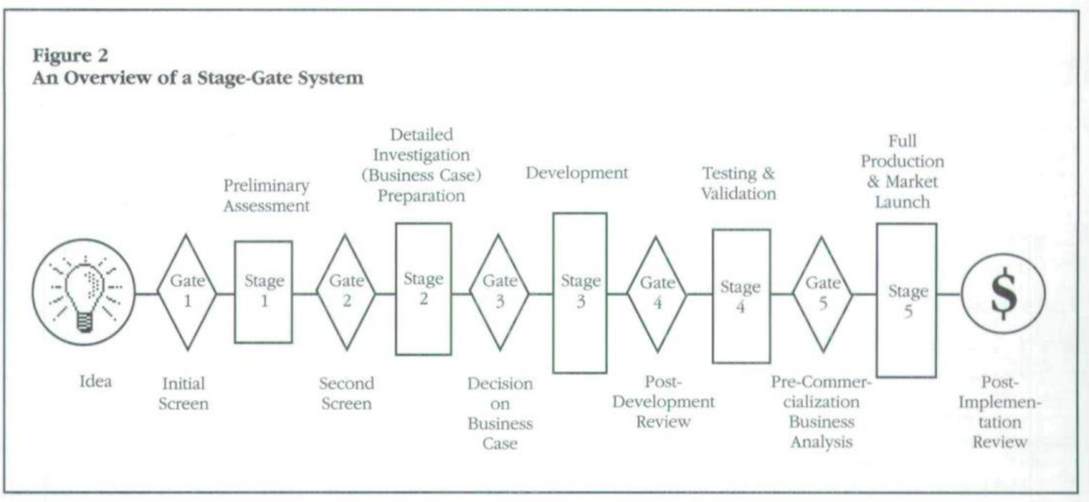

Fig. 7 - Stage-gate Model (Cooper, 1990)

The Stage-gate model envisions the multidisciplinary work in teams that have a Project Leader responsible for managing the process and gathering all the important information for decision making together with top level management at each gate. Gates are characterized by a set of deliverables, exit criteria and outputs. Deliverables are documents and important information that show the work done in each stage that will be assessed according to the criteria and metrics developed for that particular phase of the project (exit criteria) and this will result in a decision as a Go/No go/Hold/Recycle according to the previous assessment and further approval of an action plan for the next stage (output) (Cooper, 1990).

The implementation of this model aims to be a practical way to manage an uncertain process such as the creation of new products or services. Having a sequential and predefined path with previously set criteria for success, is a comfortable way for teams to develop their innovation activities. Top-level management is also protected from investment failures as all decisions are made upon the matching with the team results and the pre-established metrics. Although, it represents an important tool for managing the innovation process and being widely adopted, it has some weaknesses that may not allow this approach to meet all the needs that innovation teams have.

Despite having a broad view of the innovation process, the decisions are focused on the next gate, which might lose some important elements by not targeting the result. Also, the stage-gate approach sees innovation as a linear and well-defined process, and it might stop deviating activities that may constitute breakthrough development and relevant opportunities to explore further. And, although, it encourages the cross-functional teamwork, it doesn't clearly assume the importance of network processes to successful innovation, once it doesn't consider outside linkages rather than internal focus (Berkhout et al, 2010).

2.1.2. Value Creation Wheel

Looking into a broader approach to problem-solving, the Value Creation Wheel or VCW by Lages (2016) is a relevant example of the need that industry, science and society have to constantly adapt to an ever-changing environment. The model emphasises the importance of correctly understand the problem in order to create the best solution. The VCW is composed by two elements: DIANA, a theoretical framework that provides a holistic approach to problem-solving, and TIAGO (Figure 8), a tool with 5 dynamic and flexible phases that creates the path between problem understanding to the solution implementation.

The 5 phases consist in:

1. Tap - Research about the problem/challenge, understanding its context with a specific research question in mind;
2. Induce - After learning about the problem, it's time to induce an ideation about potential solutions. Aside from the solutions, there must be" Filters" created by someone outside of the innovation team that constitute the criteria upon which the ideas will be assessed;
3. Analyse - Management team orders the filters by importance and matches them with the existing ideas.
4. Ground - The best idea(s) are chosen and will become prototypes;
5. Operate - Development and implementation of the most viable solutions through a business model, when applicable. Solutions are assessed and defined as Go, No Go or Check, if there's the need to go back to a previous phase.

Also, TIAGO tool allows an in-depth analysis in each phase of the process by the identification of the 15 I's of innovation.

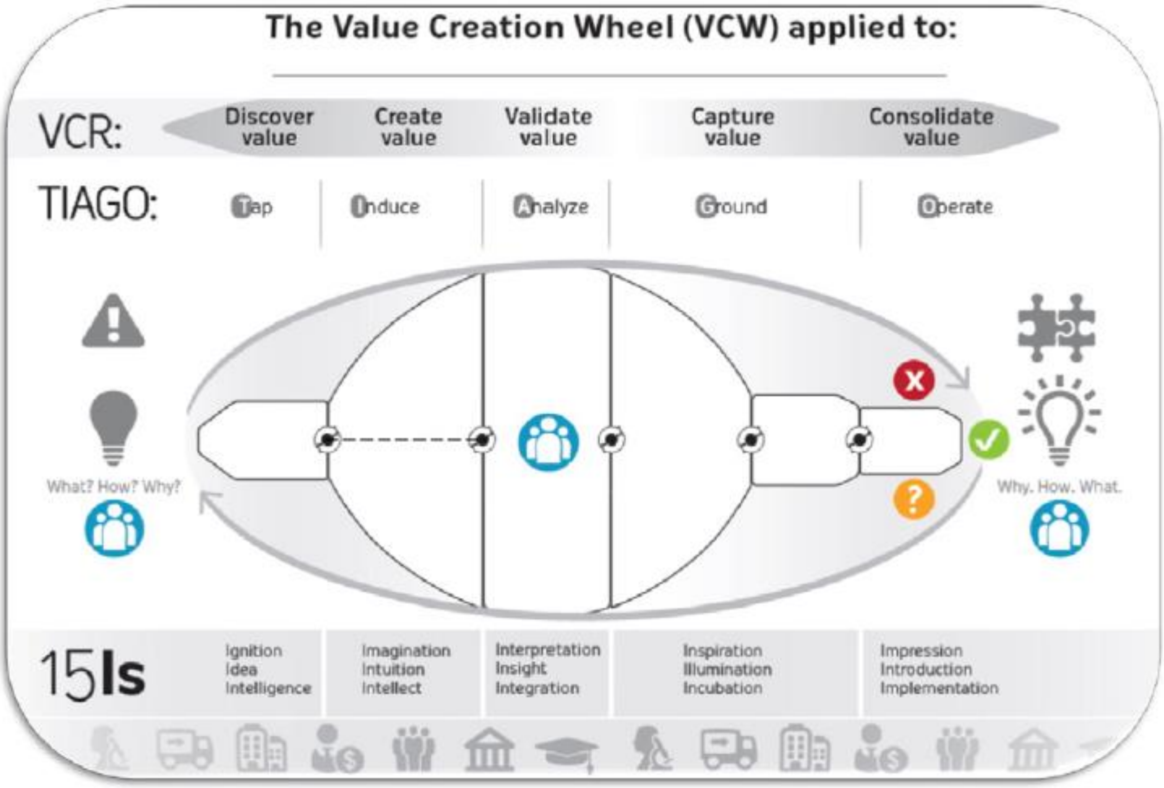

Fig. 8 - VCW: TIAGO tool (Lages, 2016)

One of the strongest assets of this approach is the ability to help with the paradox of choice. Oftentimes, innovation teams have difficulty in choosing the right path to pursue or identifying the best option to implement, and by applying the predefined filters with some level of flexibility, teams may decide objectively about further developments. This empowers innovation teams to collaborate with different stakeholders and include them in different phases of the process in order to have bigger knowledge inputs, different points of view and the setting and objective and unbiased filters. This also encourages the continuous communication between the operational level workers and the top management.

2.1.3. Customer Development Process

Nowadays, the innovation paradigm and trends are extremely biased towards a customer and user-centric approach. Industry leaders are embracing the humbleness of not believing they have all the knowledge regarding their customers but are betting on processes and mechanisms that create greater engagement with the final consumer.

The Customer Development process created by Steve Blank, and explored in the book “The four steps to the epiphany” (2006), is a structured approach to validate assumptions and build products with real desirability. The process (Figure 9) consists two parts Search and Execute, both with two iterative phases:

- Customer Discovery: Challenge preconceived assumptions and "get out of the building" to find out if other people feel or have the same problem;
- Customer validation: Checking if the proposed solution fits the customer problem explored before;
- Customer Creation: create user demand;
- Company Building: build the company for scale and implement the business model.

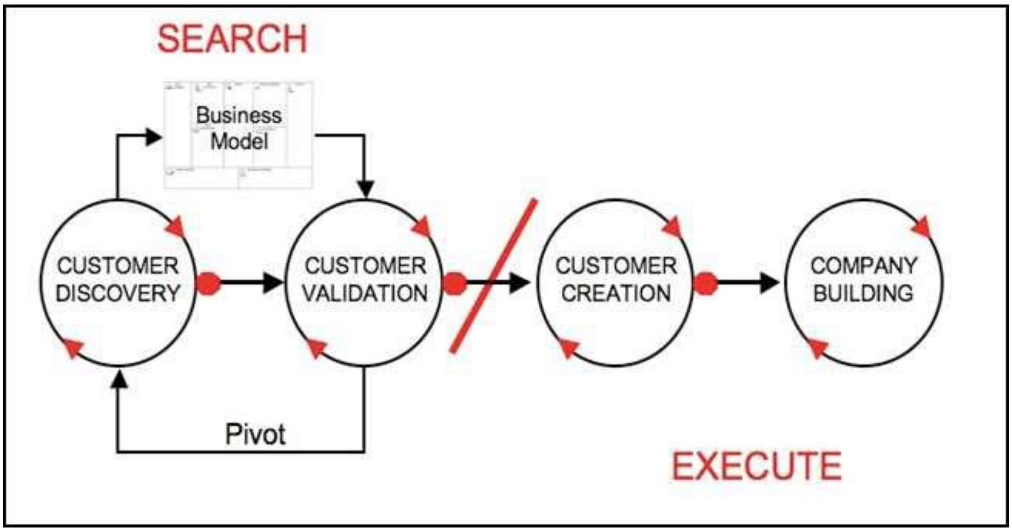

Fig. 9 - Customer Development Process (Blank & Dorf, 2012)

The first two phases of the process are the first effort to search for a viable and scalable business model. It aims at getting the innovation team or founders to get in touch with potential users and customers as soon as possible to explore opportunities and validate assumptions. The knowledge created in that iterative process allows the decision making of "pivoting" addressing the necessary changes to the initial concept or pursue further developments of the present concept.

After finding the best suitable business model, the second part of the process focuses on executing it. First building the demand for the product and raise awareness acquiring customers, and then creating an organisation that answers to that implements the business model.

This Steve Blanks' approach is the backbone for other processes widely adopted by corporates and startups. The iterative and rapid development is present in agile and lean methodologies adopted in different industries from software to automobile, and represent an alternative to the business plan and other formal structures that businesses used to rush into before getting to know their customers (Blank, 2013).

2.1.4. Lean Startup

Strongly connected with digital entrepreneurship and start-up creation, the Lean Startup approach represents a modern way to do innovation focusing on the rapid launch of a product and the continuous improvement based on users' feedback. The model created by Eric Ries (2011) has been mostly applied by start-ups, but many established corporations are using Lean Startup to do fast-paced iterative innovation (Figure 10). It represents a way for acquiring validated knowledge by challenging preconceived assumptions on the innovation project. The Build-Measure-Learn feedback loop states the importance of turn the initial concept into something tangible as soon as possible and with the minimum effort, also called Minimum Viable Product or MVP. This is a way of validating ideas and product features by allowing users/customers to experiment and assess the product performance. Which will feed the cycle by matching that information with predefined criteria that will further constitute new insights to improve the product. The goal is to continuously reduce the total time of each cycle.

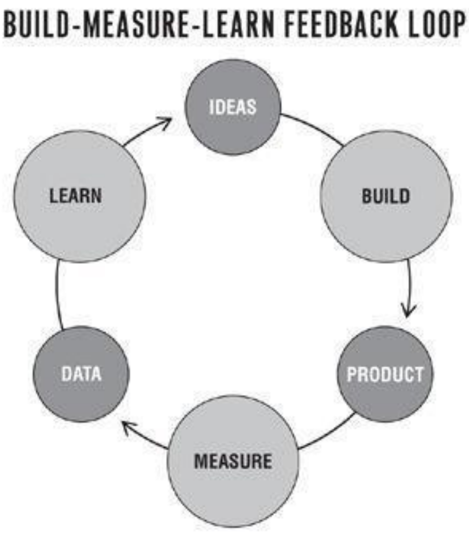

Fig. 10 - Lean Startup Model (Ries, 2011)

The Build-Measure-Learn feedback loop is the engine of new product development. It is strongly based on learning continuously and turn that new knowledge into value. The first step, Build, starts with the implementation of an MVP that requires the minimum effort to build but is good enough to enable a full turn of the cycle. The critical aspect is that it must be possible to measure its impact, only by having specific metrics the innovation team or start-up will be able to collect insightful learnings from potential customers. In the Measure step, entrepreneurs must set learning milestones to assess their progress accurately and objectively. This, hopefully, will generate insights about whether the previous assumptions are true or not. If not, at the end of the loop, the team has to decide to pivot (do critical changes in strategy according to the learnings of the previous tests) ou persevere (keep pushing and improving the current strategy).

2.1.5. Human-centred Design - Design Thinking

Businesses understood ages ago that customers could be not only the target for their products and services, but also a relevant source of knowledge crucial for the development of new products. The input of customer-sourced information into the innovation process is an important driver for diffusion and market acceptance. In fact, 70 to 80% of new product development that fails does so not for lack of advanced technology but because of a failure to understand users' needs (von Hippel, 2007). For that reason, an important effort to develop mechanisms to understand customers' needs and desires has been in place and disciplines as business, marketing, engineering and design are pursuing these methods.

Human-Centred Design (HCD) is a conceptual framework that aims at holistically understand humans for the purpose of corresponding to their needs, desires and aspirations. The word "design" has been evolving through time as it is understood not only as the abstract conception of something but also the actual plans and process required to achieve it. Putting a person in the centre of the process is radically different from departing from a scientific breakthrough or a new technological feature, it complexifies the innovation endeavours. Understanding humans, their behaviour, perception, cognition, beliefs, pains and emotions is a task that requires specific skills like empathy and creativity to perform.

Giacomin (2014) states that HCD is: "based on the use of techniques which communicate, interact, empathise and stimulate the people involved, obtaining an understanding of their needs, desires and experiences which often transcends that which the people themselves actually realised. Human-centred design is thus distinct from many traditional design practices because the natural focus of the questions, insights and activities lies with the people for whom the product, system or service is intended, rather than in the designer's personal creative process or within the material and technological substrates of the artefact." HCD aims at developing solutions that create emotional engagement with the user and takes in consideration scientific facts about human physical, perceptual, cognitive and emotional characteristics to achieve it. That way a product, system or service can introduce a new meaning into a person's life and, in turn, offer ample opportunities for commercial success and brand development. This approach accepts the need for problem solving and emphasises the openness of mind, the challenging existence of constraints and the influence of behaviours and social structures (Pullin, 2009).

The HCD model through the insights collected from observation and interaction with potential users or customers, brings important opportunities to target unexplored markets or improve existing products. Which means that the outputs of such approach could lead both to incremental or disruptive innovation. To achieve this, HCD has its own tools in order to dig deep into user research. Several methodologies and techniques were created to facilitate the detection of meanings, desires and needs, either by verbal or non-verbal means. Some examples are the ethnographic interviews (Spradley, 1979), questionnaires, role playing and focus groups (Stewart, Shamdasani & Rook, 2007), participant observation (Spradley, 1980), personas, experience prototypes, customer journey, day-in-the-life analysis, scenarios.

The shift of the innovation paradigm to a human-centred approach may have a unifying role within organizations because rather than each firm's' department work individually in their own goals and objectives, HCD could potentially turn all business dimensions into the same goal.

While the HCD model defines the importance, the tools and mindset for a Human-centred approach to innovation, Design Thinking is its extension towards a methodology that aligns the innovative endeavours with three practical elements: Human Desirability, Technological Feasibility and Business Viability (Figure 11).

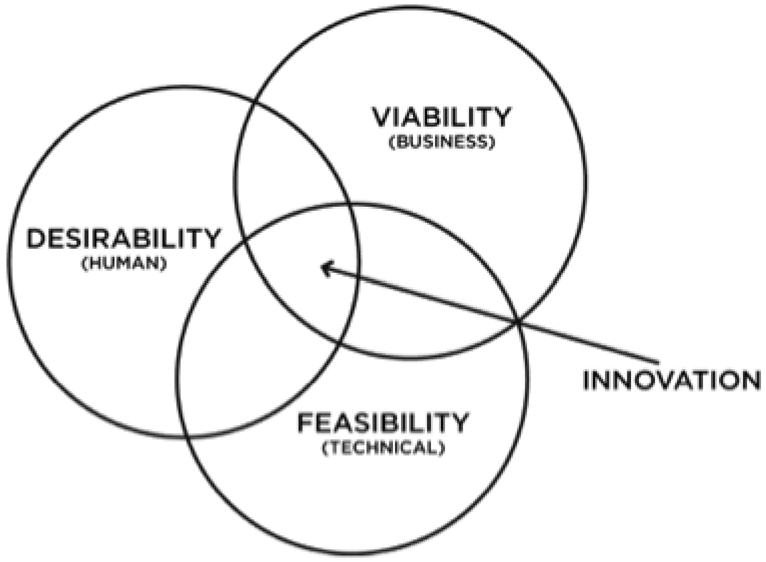

Fig. 11 - Design Thinking elements for successful innovation

Design Thinking is a human-centred methodology for innovative problem solving that has HCD as its backbone and adds particular elements from the designer toolkit allowing the establishment of an innovation process.

The first steps of design thinking were given among research groups that were exploring the way designers think during a design action (Cross, Dorst & Roozenburg, 1992), at that time the goal was to understand and improve the designers' capabilities both in education and in practice, in terms of individual and collective design processes.

Nowadays, Design Thinking has evolved and has been applied in many different domains and contexts as a problem-solving methodology. As a human-centred approach to innovation, Design Thinking is used to face complex challenges helping conceiving new realities based on the deep exploration of people's needs, while considering the available resources to bring a solution to life and the constraints and opportunities of a given situation or project (Tschimmel, 2012). The methodology mixes some dual characteristics because it demands to be at the same time "analytical and emphatic, rational and emotional, methodical and intuitive, oriented by plans and constraints, but spontaneous" (Pombo & Tschimmel, 2005). This requires from the Design Thinker a large capability of being adaptable and being able to deal with unknown contexts and situations. Design Thinking is also a human-centred innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis (Lockwood, 2010).

During the Design Thinking process only few aspects and conclusions will be linear, and the Design Thinker will face challenges when going deeper into the exploration of the problem and its potential solutions. It all begins with the application of Integrative Thinking that is the ability to encounter opposing ideas and generate a creative resolution that contains elements of both ideas but is superior to each (Martin, 2007). This requires Design Thinkers to be equipped with skills that help them to navigate through ambiguity smoothly. Tim Brown (2008) emphasizes the importance of Empathy (human-centred), Optimism, Experimentalism (learn by doing) and Collaboration (from consumption to participation), as the core characteristics of Design Thinking and its importance to deal with the uncertainty of the process. These allows to imagine and see the world from different perspectives while searching for solutions that are creative and better than the ones already existing, always believing that there's no problem that cannot be solved. Also, in search for significant innovation, Design Thinkers are able to deal with the constraints without the fear of failing through the process that is meant to be shared in a multidisciplinary team.

Design Thinking, in Tim Brown's vision, is for everybody, not only designers - "It is too important to be left to designers". The target problems of such methodology may range from internal business challenges (Elsbach & Stigliani, 2018) or for new product development (Bianchi, Santos & Borini, 2018), solving social problems (Brown & Wyatt, 2010) like the lack of fresh water in African villages or improve healthcare (Doshi & Clay, 2017; Huang et al., 2018) and education (Koh, Chai, Wong & Hong, 2015). And the potential of the solution will be increased if there is diversity of stakeholders involved in the process to bring different perspectives on the problem and complementary skills to build the solution. The process itself empowers people and communities to act upon a methodology that aims at starting to ask the right questions.

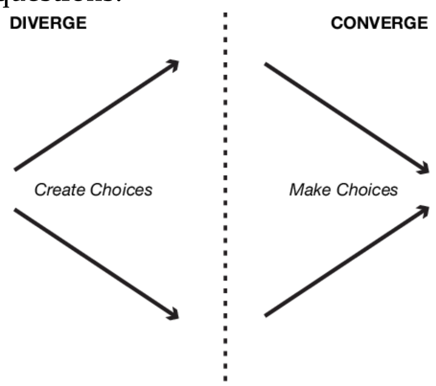

Fig.12 - Divergent and Convergent Thinking

Problems, today, are open, complex, dynamic and networked (Dorst, 2015) therefore this approach allows to creatively explore opportunities and, later, objectively make decisions considering the context, constraints and limitations regarding how well the solution responds to the problem, the technological level needed to build it and its financial viability. Since 2003, Design Thinking has been incrementally studied from the management point of view (Johansson-Skoldberg, Woodilla & Cetinkaya, 2013) and the further analysis of application projects and case-studies are evidence that it constitutes a method for organizational learning that builds competitive advantage for businesses (Cousins, 2018)

There are several Design Thinking models, all of them have the same core characteristics enunciated here, but differ in terms of process visualization and phases:

- Double Diamond (British Design Council, 2005) [1]
- Hasso-Plattner Institute Design Thinking Model [2]
- The three I Model (Brown & Wyatt, 2010)
- HCD Model by IDEO [3]
- Service Design model (Stickdorn & Schneider, 2010)

1. https://www.designcouncil.org.uk/sites/default/files/asset/document/ElevenLessons_Design_Council%20(2).pdf, consulted in 29th of October 2019
2. https://hpi.de/school-of-design-thinking/design-thinking/was-ist-design-thinking.html, consulted in 29th of October 2019
3. http://www.ideo.com/work/human-centered-design-toolkit, consulted in 29th of October 2019

One relevant innovation model that follows similar principals is the ME310 Stanford Innovation Process (Figure 13). That is the design approach used in the ME310 post-graduation explored later in this work.

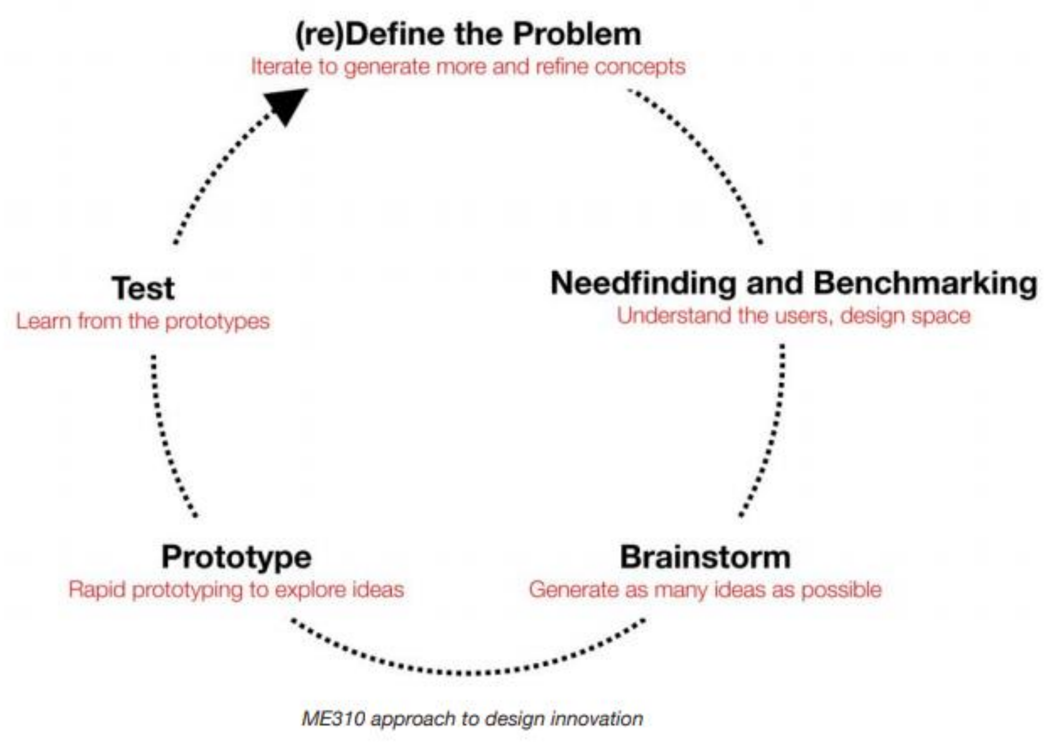

Fig. 13 - ME310 Stanford Innovation Process [4]

The process is also called "the micro-cycle" (Uebernickel et al., 2019, Wiesche et al, 2018) because of its purpose of being used along the project and to emphasize its role as a tool for learning and applying knowledge allowing continuous iteration. This model has its roots in Stanford University and in the SUGAR Network (Stanford University Global Alliance for Redesign) that bridges the gap between academy and industry by promoting innovation projects between them. The methodology allows a divergence/convergence thinking emphasizing the importance of building to learn and creatively approach a problem by targeting human needs (Uebernickel, Herterich & Hehn, 2018). The value of this methodology is understood by the exploration of each phase:

4. https://web.stanford.edu/group/me310/me310_2018/about.html, consulted in 29th of October 2019

- **(Re)Define the Problem:** This is a curiosity-driven phase where the team works on the encountered problem and frames it objectively and as neutrally as possible in order to explore the design space without influencing it. The definition of the problem must have in consideration the object, the audience and the framing conditions, and should end up with a final problem statement which may be a "How might we" question. Because the methodology is a continuous learning process, the problem may be revised and redefined according to potential new findings.
- **Need finding and Benchmarking:** Still in the problem space exploration, this is the phase to interact with the humans affected directly or indirectly by the problem. The team aims to explore needs, pains, expectations, aspirations and emotions of the stakeholders through interviews, questionnaires, observations and other HCD methods. In addition, to users' investigation, it's important to develop benchmarking activities analysing the competition and respective business models, to later support the solution space exploration.
- **Brainstorm/Ideate:** After a deep understanding of the problem and the human factors in it, this is the pinnacle of the creative activity. Ideation is when teams start to think about ways to solve the problem through one or more techniques (brainstorming, brainwrite, challenge assumptions, etc). Firstly, in a divergent way, allowing every kind of idea without judging and then, by considering project constraints and elements regarding feasibility, desirability and viability, converging to the "best" idea.
- **Prototype:** One of the Design Thinking mottos is "Learn by Doing". Design Thinkers are practical and pragmatic, therefore ideas are transformed into physical artefact in order to better communicate and further test. A multidisciplinary team with complementary skills is a crucial element for good prototyping. This phase allows to decrease the risk of building a more robust and costly object in a later phase of the project, also it may lead to new questions and idea/prototype refinement.
- **Test:** The team must not be attached to its idea and prototype, because the testing phase is about people interacting with the object created and criticizing it. Prototypes aim at Inspiring, both the team and the users to develop further improvements, Evaluate, considering the users' feedback, and Validate in terms of

- use and function. This is a critical phase that brings new insights and learnings for the team to integrate in the design cycle and iterate.

Design Thinking as a process requires Design Thinking as a mindset. It means that being applied for social good, for business purposes, policy development, or other area, it's important that the people involved are aligned and consider some relevant principles. It's crucial to empower each participant to be creative, to learn from failing, to prototype rapid and rough, to alternate between convergent and divergent thinking while dealing with project constraints and limitations and aiming to fulfil humans needs and solving the problem.

Table 1 comprises a brief summary of the innovation processes explored above. As Schumpeter (1984) stated, an innovation process has, basically, three general phases: Invention, innovation and diffusion. This means that all the approaches have a general backbone in common mas may differ in terms of the specific activities they propose in order to achieve innovative outcomes.

Some authors believe that innovation must come from the execution of a well-structured project with variances in terms of restrictions and rigidness like stated in the stage-gate model (Hacklin et al., 2009). But a different approach, more open and based on challenging the initial assumptions is also valid way to produce innovation that customers really want (Mollick, 2019). Despite it being a flexible way to deal with uncertainty and risky developments, Lean Startup is also perceived as a process that may only lead to incremental innovation, once it relies on customer's feedback not allowing to see ahead in the future (Felin, Gambardella, Stern & Zenger, 2019).

The Design Thinking method may also be criticized as a methodology that leads to incremental innovation, but some authors rely the benefits of the process on truly understanding the problem (Bukowitz, 2013). This means that instead of focusing straight away on the solution, the Design Thinking method allows a deep exploration of initial context, the problem and all the relevant stakeholders (Carden & Leonard, 2010). As highlitghted by Liedtka (2011), Design Thinking is also a tool for collaboration and learning from external sources to enrich the problem understanding and to build meaningful solutions.

	Stage-gate Model	Human-Centred Design/ Design Thinking	Lean Startup	VCW
Description	New products management process characterized by the existence of predetermined stages separated by decisions points, called gates. It comprises phases from the conceiving to the developing and launching of new products that must be specific for each firm according to its context. It implies the participation of a multidisciplinary team with a project leader that manages the process and communicates with top management in the gates.	User-centred approach to problem-solving. It advocates the participation of all relevant stakeholders in the innovation process and targets not only corporate innovation and any kind of problem. The process consists in deeply understand the problem context and the people involved, their needs, pains and aspirations. The presence of feedback loops makes it an iterative methodology that focuses in prototyping often and continuously improving it based on testing results. Ideation is an important part of the methodology that enables creative problem-solving.	Innovation process that consists in rapid and iterative cycles of developing and testing new solutions with the constant inclusion of feedback into the loop. Mostly applied to startup companies, it states the importance of building a Minimum Viable Product (MVP) to generate validated knowledge and reduce the uncertainty.	The Value Creation Wheel or VCW is composed by two elements that help identify, analyse and solve problems: DIANA - a theoretical framework that provides a holistic approach to problem-solving; and TIAGO - a customizable tool with 5 dynamic and flexible stages. The VCW aims at solving a wide range of problems with a dynamic stakeholder orientation by helping with the paradox of choice allowing an easier decision making.
Phases/ stages/steps	Idea- G1 - Preliminary Screen - G2 - Detailed investigation - G3 - Development - G4 - Testing and Validation - G5 Production & Market Launch - Post implementation review	(Re)Define the problem – Need finding & Benchmarking - Ideation - Prototyping - Testing	Build - Measure - Learn Feedback Loop	- DIANA: Define, Increase, Assess, Narrow and Act. - TIAGO: Tap, Induce, Analyse, Ground and Operate.
Strengths	- Setting of objective criteria to new product management; - Inclusion of different levels of co-workers in the process; - Interdisciplinary work; - Good connection with other business dimensions besides innovation;	- Deep understanding of users' needs; - Multidisciplinary work; - Dynamic and creative approach; - Important in the initial stage of understanding the problem and context; - Outcome led by users' feedback;	Uses classical scientific method for testing hypothesis; Suited for the entire NPD process or micro-level development;	Broad approach to understand a problem; Facilitates the decision making by applying filters to ideas generated;
Weaknesses	- Linear workflow with strict phases may limit deviating activities that can lead to opportunities; - Decisions are focused on the next gate rather than on the end of the chain; - No mention of network processes;	- Less attention to the final stage of development as final product; - Process with great ambiguity;	- Strict focus on product development, narrow connection with other business dimensions; -Customer-centred not considering innovation outputs they may target internal processes of the company; - Leads only to incremental innovation	- Model with some level of complexity may reveal difficulties to implement
Authors	Cooper & Kleinschmidt, 1986	Brown, 2008 Giacomin, 2014	Ries, 2011	Lages, 2016

Table 1 – Innovation Processes Overview (author elaboration)

2.2. Creativity and Innovation

Creativity is today understood as a broad concept that is no longer strictly connected to art and artists, but also to science, technology and business. It has various dimensions and elements that may influence its process and result. Creativity may be defined as an aspect of thinking, as an element of the personality and as the result of the interaction between thinking, personal properties and motivation. It is also considered a social phenomenon that is facilitated by some social factors or inhibited by others, for example, the setting of the workplace and its interaction with the worker may influence his/her creativity (Cropley, 2011).

In today's continuously changing business environment, firms need to constantly adapt and adjust to new realities. For that, developing the capability to face challenges creatively and be innovative, may give companies a chance to successfully manage change. Creativity is the base for innovation (Amabile et al, 1996) and therefore it must be promoted and facilitated within organizations. Oftentimes it is challenging for companies to adopt a creativity-driven approach as it needs to deal in a day-to-day basis with the pressure of being successful with incremental innovations and, at the same time, to manage the uncertainty and the risk of radical new ideas (Caniëls & Rietzschel, 2015).

Promoting workers' creativity and making it a strategic asset for the company, is not an exact science and it has led to several studies and tests such as Google that is known by its working spaces characterized by freedom, autonomy, weak rules and few boundaries and where self-expression is encouraged (Girard, 2009). In fact, the chance for the workers to pursue opportunities with an entrepreneurial mindset and being able to deal and manage uncertainty, is crucial for new product development (Blauth, Mauer & Brettel, 2014). This means that organizational culture is strongly connected with the workers' ability and motivation to be creative.

An innovative organization has a culture that provides an environment where ideas are exchanged, and creativity and creation are fostered. This requires a constant flow and proper management of individual and collective knowledge supported by a good atmosphere that motivates everyone to make part of the creative process (Lukić, Džamić; Knežević, Alčaković, Bošković, 2015). That's a relevant aspect of creativity, because not everybody feels comfortable or thinks he or she is creative and may contribute to innovative thinking.

This means the environment, the space and working process must allow workers to unleash their creative confidence (Kelley & Kelley, 2013).

Workers are more intrinsically motivated to be creative as they are placed in complex, enriched jobs and managed in a supportive noncontrolling fashion (Oldham & Cummings, 1996). A creative company relies on its workers motivation to embrace and solve problems creatively promoting an environment for sharing ideas, collaborating, having diversity in teams and allows them to have an entrepreneurial mindset giving them autonomy and independence to make decisions.

3. University - Industry Collaborations (UIC)

Higher Education Institutions (HEI) have been changing since the old paradigm of the medieval universities and are now a relevant player in the socio-economic ecosystem.

3.1. Universities as innovators

Universities were primarily established as teaching institutions that focused on knowledge and human capital development. Its role was crucial in training the future workers that would join companies with advanced knowledge and would be responsible for implementing efficiency-driven solutions and raise competitiveness in industry. With the Second World War, universities started to receive public funding for developing new technologies that would give military advantages in the field (Etzkowitz, 2001). The body of knowledge already existing in universities promoted the emergence of universities' first revolution and, from that moment on, those institutions incorporated one more mission - to do scientific research. This originated a creative tension that proved being productive once teaching and researching were converging to a broader approach to knowledge creation and transfer in universities. Later, as the role of these institutions was evolving to having a larger social impact and increasing cross-organization partnerships, universities added a third task to its mission (Etzkowitz, 2001).

The second revolution happened once universities started to generate more economically useful knowledge and technologies that had the potential to be introduced in the market as new products. Which turned universities into an entrepreneurial institution (Etzkowitz, 2001). This meant that there was an extended need for established companies to know about the breakthrough discoveries and promote its adoption, which gave place to knowledge transfer departments. Also, some of the technologies weren't being absorbed by the corporate partners which empowered researchers and universities to work together generating start-ups and spin-off companies to further develop the business idea (Etzkowitz, 2016).

Historically, universities have been playing a key role in national and regional economies and have been incrementing its contribution for social development. The evolution in universities' culture and mission has been parallel to the global paradigm of economic development, where R&D had once the central role in the whole process but that turned into a secondary focus giving place to today's vision of extensive and open cross-organization collaboration.

Firms have been both promoters and recipients of the knowledge generated inside universities. There's no doubt that knowledge is a very important intangible asset for companies that must enable to sense opportunities and have the dynamic capability of managing and adapt knowledge and complementary resources to achieve substantial competitive advantage (Teece, 1998). Adding to the knowledge-based economy demands, industry has been having pressures from the rapid technological change, shorter product life cycles and intense global competition. These companies meet universities that are now aware of its role as innovators and have pressures like the increasing growth of knowledge and funding and may find resolving responses in industry itself. University - Industry collaborations is seen as a tool for enhancing firms' capacity in innovation, creating an open environment for knowledge exchanging where external networks are the centrepiece (Dess & Shaw, 2001).

3.2. Building the relationship

A widely studied type of collaboration is the commercialisation of academic knowledge (O'Shea, Chugh & Allen, 2008; Phan & Siegel, 2006) which involves the patenting and licensing concepts developed inside higher education institutions. Commercialisation is also called technology or knowledge transfer and is the primary focus of the Technology Transfer Offices that many universities build nowadays together with rules and proceedings to deal with this phenomenon. The primary step is taken in the laboratory or in a research project where investigators build new inventions or discover some breakthrough technology or improvement that may be economically viable. Then, inventions may be patented or intellectually protected and be licensed out against the contracted receipt of royalties (Jensen & Thursby, 2001). On the other hand, established firms may not be willing to take the risk of using a disruptive technology or incorporate it into an existing product, which might result in academics turning into entrepreneurs.

The third mission of universities, besides teaching and researching, brought a whole new sense to the utilisation of its outcomes arising the paradigm of the entrepreneurial university align with the Triple Helix model (Etzkowitz and Leydesdorff, 2000). HEI use their teaching and research capabilities in fields like science and technology and, by providing educational programs on entrepreneurship and facilitating patent elaboration, those institutions are open to transfer knowledge to the community (Marques, 2016). To foster and promote the generation of new business based on scientific findings, universities are establishing incubators (Marques, Caraça & Diz, 2010). These structures aim at keeping the connection between the institution and the knowledge and expertise generated by allowing continuous development, eventual access to laboratories and facilities, and provide services as mentoring and support to further develop the technology into an economically viable product.

Academic engagement or informal technology transfer (Link, Siegel & Bozeman, 2007) is another type of collaboration that includes collaborative research, contract research, consulting and networking with practitioners (Abreu, Grinevich, Hughes & Kitson, 2009). The goal of academic engagement is not strictly focused on publishing scientific findings but also seek to generate value for the non-academic partners like offering the expertise to provide new ideas on application-oriented issues or suggest solutions for encountered problems. This is a profoundly collaborative way to co-create and develop projects to fulfil the objectives of both institutions involved. This may include temporary exchange of human capital and long-term research partnerships and joint labs. This kind of collaborations originated that 43% of all patents applications to EPO from universities and public research institutes in 2014, resulted from a co-developed project between industry and academia (OECD, 2019). Academic engagement is responsible for more applied scientific outcomes than the curiosity-driven findings of basic research (Perkmann et al., 2013). Once industry brings problems, needs, knowledge and funds to the equation, the output of scientific collaboration is adapted to its reality and is shaped to its context. Both organisations in the partnership can fulfil their goals and ambitions each of one taking different value from the collaboration.

The motivations for establishing a partnership between companies and universities are diverse and complementary, which makes this alliance a “perfect storm” that allows each organisation to pursue their goals. Ankrah & AL-Tabbaa (2015), citing several authors that contribute to UIC theory, have highlighted the motivations that lead to these collaborations. As a considerable part of HEI and research institutes (PRI) are public, governments have an important role in defining universities funding and incentives for companies. These opens the door for the collaboration in order to improve innovation efficiency and pushing economic development by capitalizing on universities’ discoveries (Barnes, Pashby, & Gibbons, 2002). From the company's’ side, this is a good opportunity to access to new knowledge created in public institutions that is only available through these partnerships. In this synergic collaboration, universities bring research expertise and crucial research infrastructure that often lacks to smaller companies that don't have internal R&D capabilities. Firms know exactly how to turn scientific breakthroughs into new products and how to apply market knowledge to leverage product development.

Interorganizational collaborations represent also, an opportunity for universities' funding besides the public money they receive for research. Oftentimes, funds from industry are far less bureaucratic and easier to reach. Also, if the output of the cooperative project is a protected technology, this may represent additional revenue for universities by licensing it. These extra forms of funding may generate more autonomy and independence from public investment (Logar, Ponzurick, Spears & France, 2001). On the other hand, these represent a cost-effective investment because they fund already existing expertise, resources and facilities, and may capitalize in a serendipitous outcome that turns into an innovative and disruptive product (George, Zahra, & Wood, 2002). This leads us to the obvious motivation for industry to seek partnerships with academia, that is to pursue financial gains with the outputs of that co-creation.

Analysing the importance of human capital in this relationship, it is important to comprehend the relevance of human interactions and individual contributes for the cooperation. Both parts take value for their personnel from this partnership. Universities have the opportunity to improve their teaching and research offer allowing students to get in touch with industrial and business environment, the most up-to-date insights from industry research, real case studies and practical industrial problems (Santoro & Gopalakrishnan, 2000). This is critical for universities to train experts and present them to job opportunities in industry and equally important for companies to acquire employees with advanced knowledge and the best students to hire or invite to an internship (Ankrah, Burgess, Grimshaw & Shaw., 2013). Also, this collaboration may contribute to already existing employees to refresh and acquire new knowledge that may be later introduce to companies processes and products. As well as professors and investigators that are able to contact with the industrial state-of-the art facilities and expertise to enrich further investigation or teaching inputs.

Collaboration with top universities may be a relevant contribute to increase company's prestige to the its stakeholders (Siegel, Waldman, & Link, 2003). It may represent the quality and the investment on research and new product development that influences customers and competitors to act on it. In the universities' perspective, collaborations with well-known firms is an important factor to raise public awareness about the quality of its researchers, education programs and facilities. This may represent increased interest from the brightest professors, students and researchers to work together with that institution and facilitate new collaborations and funding.

Innovation ecosystems are powered by these kinds of relationships that aim at raising national and regional competitiveness by social and economic development. At the table seat both Universities, Industry and Government to architecture a symbiotic relationship that fulfils each one objective and push forward science and technology (Etzkowitz & Leydesdorff, 1998).

The evolution of the mission of an ancient institution as the university and it continuous opening to the society and the impact of its contributions in the economic development, raised the interest to research deeper into the University-Industry collaborations. The way corporations innovate was highly disrupted throughout time and the university is, today, a key player in co-developing scientific and technological breakthroughs. Therefore, this work will focus in a program that brings together companies and universities to collaborative innovation projects through the Human-Centred Design methodology with a closer view to the relationship between Porto Design Factory from Porto Polytechnic and IKEA Industry Portugal.

CHAPTER 2. RESEARCH METHODOLOGY

1. Objectives

This research work aims at presenting the theoretical state-of-the art regarding the current economic paradigm and its effects on business innovation. A comprehensive understanding of the evolution of the innovation approach that firms have been applying through the years and its adaptation to the continuous economic, social, political and technological changes, will help to better justify the current collaborative partnerships between organizations.

Therefore, the goal of this study is to explore and explain a specific context of university-industry collaboration and take the respective learnings when comparing it with the theoretical exploration available on Chapter 1. The context to be studied is the partnership between the company IKEA Industry and the higher education institution, Porto Design Factory (from Porto Polytechnic), for developing an innovation project under the educational program "Post-Graduation ME310 - Product and Service Innovation" 2017/2018.

The specific objectives of this work are:

a) Understand the potential of university-industry collaborations for innovation purposes;
b) Identify the motivations that led to the collaboration between Porto Design Factory and IKEA Industry;
c) Describe the outcomes of the collaborative innovation project regarding developed concepts, prototypes and final proof of concept;
d) Identify the benefits of the partnership for both organisations in terms of incentive to creativity, problem resolution, and adoption of an innovation culture;
e) Understand how IKEA Industry does innovation internally, how is it protected and what are the current themes in development.

The expectation is that the results of this investigation will provide clear findings regarding the motivations of each organizations to partner for innovation purposes, the mechanism by which they did it and the value generated for both. An in-depth look will provide insights relatively to the architecture of the relationship regarding which kind of agreement was made, resources allocation, objectives for the partnership, and the role of each organization and its contribution for a successful project. Investigation efforts will target the internal environment and changes in the firm to allow and promote this collaboration, as well as a close understanding of how the university organized itself to provide innovation both as a service and as an educational program. Without further research it's possible to infer that this collaboration is different from the frequent technology transfer and licensing partnerships and it is not an obvious case of contracting a research project with high-skilled investigators. But rather an organic relationship developed during the time of the program where both organisations interacted and were involved in the process of innovating.

2. Methodology

2.1 Investigation method

Social sciences as sociology, psychology, political science, and business, have been developing several useful research methods to understand complex contexts and environments. To understand a given reality, different approaches may be used to collect, analyse and present research findings.

The proposed investigation represents a real-life event and several complex variables that contribute to the to-be-studied situation. It refers to a specific occurrence in time and well-defined intervenient that turned the context into a one-of-a-kind event. Therefore, the investigation needs a rich exploration and description of the given event allowing to retain the holistic and meaningful characteristics of it.

The research method used will be the Case Study. It aims at explaining a given situation by answering to How and Why questions proposed by the investigator that has little to no control over the event and that focuses on a contemporary phenomenon within a real-life context (Yin, 2009). The case study begins with the establishment of research questions and its propositions in order to align the investigation endeavour and promote a logic connection between the goals of the study and the findings. It is strongly driven by qualitative data that enriches the knowledge of the targeted object and preserves the information acquired. The method is designed to allow the collection, analysis and the sharing of scientifically treated information regarding a social phenomenon. "It tries to illuminate a decision or a set of decisions: Why were they taken, how were they implemented, and with what result" (Schramm, 1971).

The effort of "seeking the particular more than the ordinary" will allow to point out the uncommon of the phenomenon and its contribution to broad the knowledge of a previously studied field or situation (Stake, 2000). Being contradictory to the generalization-producing studies, the case study may allow the deep understanding of a given reality by highlighting unique characteristics that may be further explored in other cases.

Many sources of information will be considered to further develop this case study. Structured interviews will be one of the main methods to collect insights from the elements involved in the different phases of the project. These will be targeted at workers of the company, responsible people from the university and the students enrolled in the post-graduation. Also, the delivered documentation, photos, reports and other available outputs of the work developed by the team of students will be considered to complement the interviews' data. Although many internal documents were shared by the company, only allowed information regarding the organization will be available in this case study to preserve sensitive information regarding internal processes and activities.

The technique to extract valid and relevant information from the data sources stated above, will be the Content Analysis (Bardin, 2011). That provides a systematic and objective procedure to collect insights from the available content that allows to take inferences about the reality to be studied.

2.2. Sources of Data

The case study will rely in different sources of information and the data type will be mainly qualitative. The team of students involved in the project aggregated all the documents produced and collected in a shared folder in order to provide remote access and distributed collaboration. The author of this work has the access to this folder as well as personal knowledge regarding the case by being one of the team members.

The documentation available are divided in internal documents due to team collaboration for synthesizing information from research, field work, discussions, and others. And, also, "official" documents that were due to be delivered both to the teaching team and company with all the knowledge gathered, research results, prototyping and testing information and reports on every development. Examples of these are the quarterly extensive reports (Fall, Winter and Spring), and one or two documents per prototype, depending on the situation. This constitutes a large and reliable database with the teams' findings and the path taken during the case.

Other important source of information will be the interviews. It will provide relevant insights ranging from an organisational perspective to a more personal one, depending on the interviewee. Those will be:

- **Nuno Santos – Head of the Innovation Department of IKEA Industry Portugal**: The interview was semi-structured and took 43 minutes. It was recorded and aimed at collecting relevant data regarding innovation inside IKEA group and, more specifically, IKEA Industry. What are their internal and external sources of innovation, how do they protect it and which are the processes by which they innovate, are some of the topics to be explored. These corporate aspects will provide information about the reasons and motivations for the company to collaborate in this kind of projects with universities, and their expectations. The guide of that interview may be consulted in the Appendix 1.
- **Rui Coutinho – Director of Porto Design Factory and ME310 program:** Prof. Rui Coutinho was the PDF's Director at the time that the case occurred. He provided information regarding the motivations for the university to develop a program with the specificities of the ME310 and which was the expected impact of such program both in companies, the universe and the students. Also, there were questions about the policy for protecting innovation, the methodology used in the program, its benefits and challenges, as well as the particularities and having a higher education institution collaborating with a company. The information was collected through different informal conversations and written memos were done. The questions may be consulted in the Appendix 2.
- **Márcio Silva – Corporate Liaison**: Dr. Márcio had the role of being the intermediary between the company of the university for this specific project. The telephonic interview took 30 minutes and the audio was collected to allow later revision. Also, some information was kept from previous informal conversations. He shared the importance of having a person doing this kind of work, the difficulties and the impact in both students and the company itself. Also, he represents an important vehicle of knowledge between the two parts and may talk about how the project outcomes were integrated into the company and which changes did it bring, if any. Interview guide available at appendix 3.

- **Cláudia Legoinha and Rita Silva – Team members**: Both team members were interviewed for approximately 30 minutes and several informal conversations were taken. They provided important insights regarding the relationship with the company, the balance between the control and the freedom to make decisions. And with the university, the different opportunities and resources available for learning and developing the project. Also, it allows the understanding of the impact the course format and educational approach. Interview guide can be found in the appendix 4.

The data analysis will be focus on the discourse and the narrative obtained from the interviews and the content of the available documents. To get a comprehensive understanding of the phenomenon it will be used the triangulation strategy to analyse the qualitative data (Patton, 1999). This will provide the understanding of the data collected and the convergence to a final analysis of the topic of innovation and University – Industry collaboration.

CHAPTER 3. CASE STUDY: IKEA INDUSTRY'S HUMAN-CENTRED DESIGN PROJECT

1. IKEA Industry: Company Overview

It all started in the 1940's in southern Sweden where Ingvar Kamprad initiated a small business selling through a mail-order catalogue. The poor roots of his business and the culture lived in that region of the country made the backbone of the company IKEA is today.

The IKEA Group employs 211 000 co-workers, had 41.3 billion euros in revenue (FY2019) and has 433 stores world-wide, exploring 50 different e-commerce markets. It's vision is to "create a better everyday life for the many people" and, in practice, it aims at "offering a wide range of well-designed, functional home furnishing products at prices so low that as many people as possible will be able to afford them". To achieve this, the company focuses on a business model that is explained in a circular relationship between providing better products and lower prices enhanced by having higher volume and lower costs.

A key part of IKEA's value chain is the manufacturing of its products that some are handled to suppliers and others are produced by another organisation inside the IKEA Group.

IKEA Industry is responsible for the manufacturing of some of the furniture sold in IKEA stores with 40 production units in 10 countries and 19 000 co-workers. This entitles IKEA Industry as the biggest wood and woo-based furniture manufacturer in the world with its top production being in Poland, Russia, Slovakia, Portugal and Sweden. The company is divided in 4 different divisions: Flatline, Solid Wood, Boards and Purchase. Flatline is a range of products with specific characteristics ranging from manufacturing materials and techniques, to the well-known flat packaging by which IKEA is able to enhance distribution by accommodating bigger volumes, ultimately providing a better experience for the final customer to transport its furniture. The factories have to respond to IKEA of Sweden which is the owner of all intellectual property and defines which products will be sold, which will be produced by the group and all the guidelines to do it. Alongside factories, another organisation is crucial to the development and testing of new designs – the Product Development Centre or PDC. One of the most relevant is in Poland, close to the biggest factories in Europe. PDC is responsible for doing innovation in terms of the materials applied to the furniture and new technologies that may enhance customer experience and production. The knowledge generated there is created together with factories and is due to be disseminated by all the distributed teams around the globe.

IKEA's competitiveness is in its ability to efficiently manage a long value chain from knowing and learning about its customers, to the designing of quality products and further manufacturing, packaging, distribution and selling. Also, the company has developed relevant efforts to follow global trends and have highly skilled workers to perform above the average. In 2014, the group defined the IKEA Group Manufacturing Strategy 2020 where all the guidelines and were set envisioning the constant growth and improvement of the company. In this document knowledge was considered a strategic asset which was translated into:

> *"We possess knowledge within the area of manufacturing valuable for the development of other IKEA processes as well as IKEA suppliers. We will make this knowledge available by being open and transparent as well as sharing best practice.*
>
> *We will be active among IKEA suppliers, industrial networks and the academic world to secure that our knowledge within the area is leading edge.*
>
> *We will promote mobility cross organisations to increase manufacturing competence where needed."*

This was one of the strategic steps towards knowledge transfer efforts that led to interorganisational partnerships like one presented in this case study that lead us to the IKEA Industry factory in Paços de Ferreira, Portugal.

IKEA Industry Portugal S.A is the only industrial facility of IKEA in Portugal, it employs 1512 people and has a revenue of over 190 million euros (FY'18). According to Nuno Santos, Innovation Director of the Portuguese facility, every factory seeks to accomplish the mission of satisfying the "many people" and that means to provide interesting deals to the factory's client – IKEA of Sweden. The aim is at delivering quality products at low price which means efficient manufacturing and innovative approaches to production while exchanging knowledge.

The factory is placed in a geographically important place for the furniture industry in Portugal as Paços de Ferreira is known as the "Capital of Furniture" and has the most skilled and knowledgeable workers in the field. It is also not too far from shipping ports, driveways and, relevant sources of knowledge, like the higher education institutions of northern Portugal.

2. Polythecnic Institute of Porto – Porto Design Factory

Polytechnic Institute of Porto is a higher education Portuguese institution that's composed of diverse polytechnic schools based in Porto. It was created in 1985 but its roots back in 1852 with the Porto Industrial School. Today, it ministers several different courses in domains like education, management, engineering, music and arts performance, health, media arts and design, and hospitality and tourism. Porto Polytechnic is also a relevant producer of scientific investigation having 24 scientific research groups in its eight schools.

In 2014, to build a structure to focus on innovation and be an agile interface with industry, Porto Design Factory (PDF) was created. PDF is a global platform based on interdisciplinary work, applied research and industrial collaboration. Many students through the years have been joining its educational courses with strong emphasis problem-solving methodologies together with industrial partners. One of those programs is the ME310 that its roots in California, USA.

2.1 ME310 – Product and Service Innovation

Deep inside Silicon Valley resides an organization that is known for its innovation drive and the many successful entrepreneurs that were raised there - Stanford University. Since its origin in 1891, it has been an important teaching and research institution that in the early days was focused in arts, technology and engineering and was changing the American landscape at the time.

Stanford has a long-time relationship with companies and many activities are done collaborative with industry, maybe the reason for it to be at the centre stage of innovation. ME310 was one of those initiatives that meant to allow quality teaching and reinforcing the connection with firms in the valley. Back in 1967, the initial versions of the course were targeted to graduate students from engineering design that aimed at involving the student in the design-development process. A later version of the course was relying on the analysis of case studies and company's records in order to learn from real life situations and understand the process of engineering design practitioners. In the 70s the course turned into a more practical approach to designing and building hardware with an extreme focus in learning by doing. The results were much appreciated by industry that rapidly wanted to make part of the program which represented an important opportunity for students to learn from real problems and contexts (Carleton & Leifer, 2009).

The course had a considerable evolution since its early days and turned into a global landmark of university-industry collaboration for innovation purposes. The initial efforts to interact with local companies and involve Stanford's students resulted into a worldwide spread of the program through different universities and bringing diversity in terms of corporate partners and students.

Today, ME310 is a year-long course in which students work in teams to solve real-world problems provided by industry sponsors. Each team addresses a given problem statement and by June they are responsible for designing and building a functioning prototype. Students are challenged to question, embrace ambiguity and learn by doing, as the course focuses on Problem-Based Learning methodology. Besides the technical skills that students may have and further develop during the course, the program is designed for strongly emphasize teamwork, collaborative skills, critical thinking, planning and complex problem-solving, as core competencies for the competitive job market (Carleton, 2019). Since 2005, ME310 became a global program envisioned by Professor Larry Leifer to mimic the distributed team process used in industry. In 2011, SUGAR Network (Stanford University Global Alliance for Redesign) was formally created and it opened the door for other institutions to make part of an international group of universities that apply the same educational model and similar format. In 2018, 31 global projects were developed with organisations like Aalto University, Hasso-plattner Institute, Karlsruhe Institute of Technology (KIT), Trinity College Dublin, Kyoto Design Lab, Porto Design Factory and many others.

Companies become corporate sponsors by engaging with one of the universities and sponsoring one or more teams providing a design brief (challenge). Companies have been proposing technically driven problems but also there's an increasing interest in services, innovation and emerging technologies. The companies joining the program are very diverse in terms of size, social mission, sector and in the different editions some of them were BMW, SAP, Sanofi, Allianz, Ford, Merck, Roche, Swisscom, etc. As the university partners are spread all over the world, also the corporate partners may be multinationals or local companies.

Teams of students are assembled according to their background, profile and interests. The main goal is to provide diverse, balanced and multidisciplinary teams to bring different perspectives, knowledge and skills into the project. Teams are often divided in two locations. International collaboration allows students to work in remote teams to enhance the group capabilities to answer the challenge and the access to different resources. Teams are led by local teaching teams that help with the applicability of the methodology of the course and facilitate the process through the year. Commonly, the teaching team has professors and teaching assistants that are students from previous years that give special insights from as the ones that already have passed through the process. Also, coaches and industry experts get in touch with teams to promote exchange of experience and knowledge.

ME310 is an intense and creativity-driven program which translates into the necessity of having appropriate facilities to empower students to become comfortable with being disruptive and thinking openly. Therefore, university partners provide a dedicated space for the class to use during the year, known as the ME310 Loft. In this physical space, students find artefacts from priors' years in order to inspire them to make tangible their ideas and concepts and pursue the success of previously developed projects. Also, students must feel the space belongs to them and freely adapt it to its collective needs and desires. This allows the free flow of work and space utilisation as well as cross-pollination of projects. The course has also an important weekly moment called SUDS - Slightly Unorganized Design Session. SUDS is the moment for the class to have dinner together in an informal environment in order to exchange experiences and foster the sense of community.

The "vehicle" that drives students through the program are the Macro-process (Figure 14) and the Micro-Cycle also known as the ME310 Stanford Innovation Process explored in the second topic of Chapter 1.

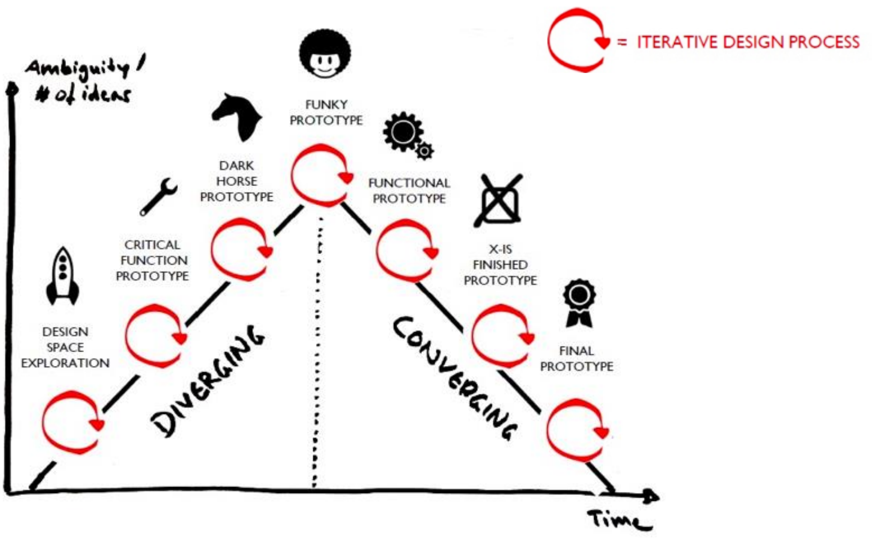

Fig. 14 - ME310 Macro-process

The macro-process is the visual representation of the different phases of the ME310 program during its 3 quarters. It represents the different prototypes and concept evolutions from the beginning of the project until the final proof of concept. Each iteration should be the result of previous research and user testing in order to do constant improvements.

It all starts with a briefing and problem description from the corporate sponsor, that may represent a completely new field of knowledge for the team of students. In the Fall Quarter, there's an intense phase of research both through secondary sources and *in loco* observation and immersion in the space/situation to be addressed. The design space exploration allows the team to synchronize with the problem and have more in depth insights regarding the situation given by the corporate partner and the stakeholders involved. After the first exploration and ideation efforts, the methodology forces teams to be hands-on and build their first prototype called "Critical Function Prototype" (CFP). CFP allows the team to explore a first concept and testing it from a functional perspective, it is expected to be a rough and rapid prototype with the minimum effort to prove a certain functional characteristic, not the whole prototype. Each prototype has to be carefully thought in terms of what it is, why it will be done, how it will be built. Testing the prototype will bring many insights that have to curated and translated into learnings. Those are the relevant information that will allow improvements in the next iterations.

The second prototype of the Quarter is the "Critical Experience Prototype". At this stage the team already knows a substantial part of the problem and the people that impact or are impacted by the problem, for that reason the next prototype will provide an important moment to interact with potential users creating an experience. Because it is an early prototype, it doesn't mean that the experience provided must be directly connected with the final solution, because there's none at this point. It is due to collecting even more knowledge regarding a specific situation that the team doesn't have access to, for example, how people feel in a given situation, how do they interact with a given artefact, etc. It's about collecting emotions and the real feedback given by users to further explore and create meaningful understanding of the user.

Each Quarter ends with a comprehensive documentation of all the research results, prototyping and testing results, even exploratory hypothesis chose not to follow. All this information is critical to understand which markets were researched and why some paths were developed further, and others didn't. This constitutes knowledge that the company will have access to and may integrate internally in future new product development efforts or market explorations. The Fall Documentation compiles the knowledge generated in the project and a design vision for the future. The team and the company worked side by side to create a clear understanding of the problem to be addressed but, at this point, there's no evident idea of what the actual solution will be.

In the Winter Quarter the exploration of the problem is extended, and the pinnacle of the divergent phase will have place before the initial steps of convergence are given. The continuous research and concept iterations usually generate wild ideas that are less believed to be feasible or viable. The first prototype of the quarter is the "Dark Horse Prototype". The dark horse is understood as the one that is less likely to win the race and, therefore, nobody bets on him. In innovation, the incremental improvements may sustain growth in a long term, but radical breakthroughs are often the reason for companies to differentiate themselves. Because, radical innovation is risky and less likely to succeed, ME310 provides the right "flight simulator" to test this kind of concepts. The Dark Horse prototype is the moment in which teams challenge their most radical assumptions and ideas, turning concepts tangible and that in another context wouldn't be even tried. Despite being a bold concept, it doesn't mean that it has to be perfectly built, the goal continues the same of allocating the minimum resources and effort to have a meaningful learning experience. At this point, companies are challenged to not influence the team development even if it seems out the firm's strategic scope. The result of this prototype might not be the artefact itself but mostly the information and new insights it will provide. The last prototyping effort in the divergent phase is the "Funky Prototype" that aims at iterate in the Dark Horse prototype to make a better version in terms of functionality and aesthetics integrating the learnings from the previous tests in order to explore the maximum potential of the wild ideas.

The convergent phase begins with the "Functional Prototype". The team must revise all the knowledge generated about the problem and all the learnings from previous prototyping and testing and decide the final concept to address in future developments. It's time to embrace a specific solution that may suffer changes and adaptation through the next phases, but that will keep the same concept until the building of the final proof of concept. The Functional Prototype is the first version of this concept that might come from old ideas, from the dark horse or, most likely, the integration of different concepts that proved to be relevant for users through the several iterations. This represents the end of the Fall Quarter with the elaboration of one more documentation aggregating all the knowledge generated and results that are shared and revised by the company.

The Spring Quarter is the last part of the ME310 program where teams are already in solution space working in what will be the final solution presented to the company. The goal of the program is to deliver a prototype reliable in terms of functionality, not a final product, but a tangible concept with the final materials and features, and close to the solution the company might integrate in its portfolio. The first prototype of the quarter is the “Part X”. The goal is to secure that the main functionality of the final solution is done and properly working. In the case of a software, it has the main function properly developed but additional features and user interface might be incomplete. Further developments lead to the final version of the solution where all is fine-tuned and presentable both to users, for a final test, and the company. The project ends when the company possesses all the documentation and prototypes.

Each University that provides the ME310 program has adaptations of this core organisation. The ME310 Porto is one of the few that is structured as a Post-graduation program, in order universities might be an year program of the master's degree or a specific curricular unit.

The ME310 Porto 2017/2018 had 21 students divided by 7 teams. Each team worked together with fellow students from other university and a corporate partner:

- University of Saint Gallen and Generali
- Aalto University and NOKIA
- Warsaw University of Technology and Philip Morris International
- Trinity College Dublin and WORTEN
- Kyoto Design Lab and Triwool
- Design Factory Melbourne and SONAE MC
- Warsaw University of Technology and IKEA Industry

The present case study focuses on the last project of the list in which 3 students from Porto Design Factory - Cláudia Legoinha, Rita Gomes and Tiago Silva - worked together with 3 students from Warsaw University of Technology - Anna Sarnowska, Edyta Trepkowska and Karol Radziszewski. The team worked together with IKEA Industry, which had been sponsoring ME310 projects for the two previous years. The proposed challenge was “Eliminate drilling in wood furniture mass manufacturing”, more information regarding the problem briefing might be found in the Annexe 1.

The agreement made between Porto Design Factory and IKEA Industry (Paços de Ferreira) stated the payment of a project fee and included the delivery of all the documentation produced during the program, giving the company all intellectual property of the knowledge generated, the final proof of concept with the respective customer validation, a set of Design Thinking workshops for the co-workers and access to the university facilities and resources according to the needs of the project. It was made possible, also, for workers of the company, specially the corporate liaison, to be involved in the program's activities, trips and presentations.

3. Human-Centred Design Case

The ME310 Global Kick-off took place in the heart of Silicon Valley, in the Santa Clara Convention Centre, in November 2017. At the stage, Professor Larry Leifer addressed the 100+ students that were initiating a program they didn't fully understand yet by stating that they would to learn to "*Dance with Ambiguity*". In a room filled with students, teaching teams and corporate representatives, only the ones that new ME310 before understood the meaning of those words. At that time the teams already knew their challenges, their distributed team members and corporate partners. For one week they were put to proof being challenged to do a full micro-cycle with limited time, resources and knowledge, to create team dynamics and give a first glance of what was expecting them during the next 10 months.

IKEA Industry team faced a briefing that none of the elements fully understood. "Eliminating drilling from wood furniture mass manufacturing" was out of the scope and experience of the Biomedical Engineer, Physicist, Biotechnologist, Nurse, Product Designer and the Mechanical Engineer. The first analysis and research showed the problems related to the drilling process in terms of dust generation and impact of the working environment and from the efficiency perspective being the bottleneck of the manufacturing process.

The initial exploration of the problem and the first ideation process led to the prototype of a needle-shaped drill (Figure 15). The assumption was that as the needle punctures the skin it would also create a hole in chipboard without the messy dust. Which soon failed.

Fig. 15 – Cardboard and Plastic Prototypes of Needle-shaped drill (sourced from team)

FALL QUARTER

Back in Porto and Warsaw, the team started working in Redefining the Problem. Exploring each word of the briefing individually and research to understand the impact of the drilling process for that to be considered an issue. To holistically understand the problem the team needed a broader knowledge about the factory, the manufacturing process, the materials, the workers flow and working conditions. This included a deep research on the internet and specialized publications in order to have a broad vision of the design context at this point.

An initial drawing of the stakeholders map (Figure 16) provided the understanding of which people and organisations were involved in complex industrial arrangement and who could influence or being influenced by the given problem.

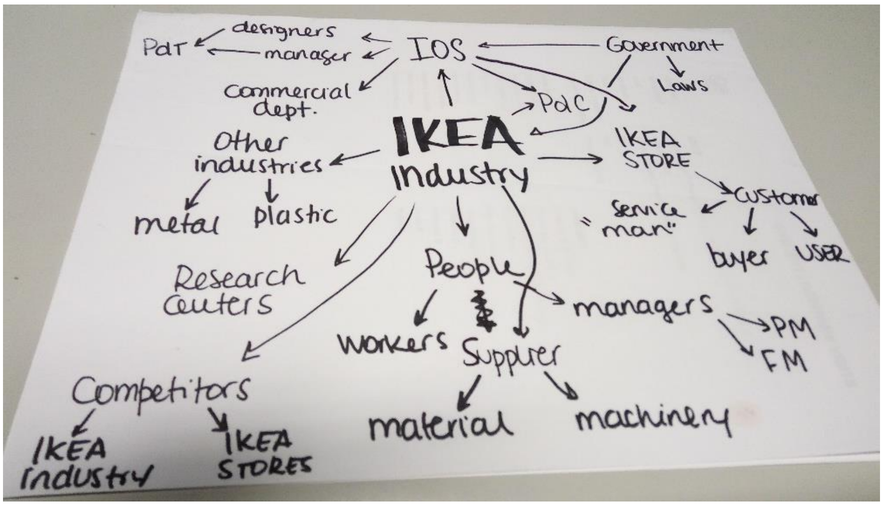

Fig.16 – Teams’ first stakeholders map (sourced from team)

After roughly understand the context, both sides of the team were able to visit an IKEA Industry factory, one in Paços de Ferreira (Portugal) and other in Zbąszynek (Poland) to initiate the phase of Needfinding and Benchmarking. The field research allowed not only to check the manufacturing process and understand the business, but also to connect with ground workers and managers to empathize with different perspectives of the same problem. The carried out several interviews to different workers from the technical department ranging from Product Engineering, Industrialisation, Equipment and Property. The initial assumption that the team faced was that the problem was heavily concentrated inside the factory, so the team explored different stakeholders like the clients at the stores’ doors. Around twenty face-to-face interviews allowed the students to understand hidden opinions about IKEA and IKEA furniture, and the experience the customers were having when buying the furnishings. Also, thirty-three people responded to the online survey on social media.

The benchmarking exercise (Table 2) was carried out by visiting five other companies from the furniture industry, plastics and composites, and cork. That allowed to check how other companies were dealing with similar industrial processes or associated problems.

Problem	Impact	User
Drilling generates dust	- Dirty work environment (health issues, risk of fire) - Heavy costs managing dust (Exhaust Ventilation, Respiratory Protective Equipment, sprinklers) - Dusty products for the rest of production process (coating, packing)	Ground Worker Management Customer
Drilling is the bottleneck of the assembly line	- An efficient manufacturing process gets to 60m/min, drilling is the part of the process where it slows down (machine's setup, precision, adjust positioning)	Management Customer
Reduced functionality	- Users reported that predefined holes in furniture doesn't provide customization options (eg. Cabinet with shelves)	Customer

Table 2 – Main findings from Needfinding and Benchmarking (sourced from team)

The first glimpse of the project provided a clear understand of the real impact of the given challenge. IKEA's business model relies on reducing costs of production, to have better prices, to raise the demand. That's the backbone the logic behind having a close-to-perfect assembly line, efficient to the second, to provide better deals to the many people. Complementing the information from all the other sources, the weekly meetings with the corporate liaison, Márcio Silva from the Equipments team of the Technical Department, provided insightful learnings regarding the production line and the machinery used in the factory.

In order to summarize the learnings and reorient the project towards its humans' factors and impact, the team chose the tool Persona (Figure 17). It allowed to fully understand specific needs, ambitions and desires of a given character that would, in its own way, concentrate the problems and impact explored before. The three personalities identified had different roles as stakeholders in the context: Ground worker, Manager and Customer.

PERSONA ID - customer

Jerónimo Kawalski
31 years old
International Relations
Moved to a new city

Pains:
- New city, new job
- Assembling and desassembling furniture
- Can't adapt his cabinet shelves to his needs
- Instructions manual not intuitive

Needs:
- Easy-assemble methods
- Affordable furniture
- Customization Options

Fig. 17 – Simplified example of the Customer Persona (sourced from team)

After "getting out of the building" as the teaching team was pushing the team to do, it was time to enter the solution space.

Until the end of the quarter, the team had to design and build two prototypes: Critical Function Prototype (CFP) and Critical Experience Prototype (CEP). It was time to be hands-on and to start exploring concepts, more than thinking about final solutions. These prototypes aim at exploring and diverge, and test assumptions regarding the problem faced. It was meant to be developed roughly and rapidly, with the minimum allocation of resources possible. Before each prototype, the teaching team challenged the teams to elaborate a document with simple questions like Why, How, What, Description of the test and Learnings. That way the team could put on paper the reason why they chose to build a particular prototype, how would they build it, how would they test it and it was a way to synthesize the testing results and collect learnings for further developments. These deliverables were meant to provide evidence both for the teaching team as well as for the corporate partner.

CFP was the moment to test a functional feature in an exploratory way because the team didn't have enough information and data yet to truly decide which path to take or even which were the right questions to ask. The two halves of the team focused in two different contexts: The industrial process and the furniture assembling.

For the industrial process, the team brought back the initial concept that they had prototype back in California, the needle-shape drill. The assumption was that a drill like that would puncture the chipboard in a clean way not creating dust. It was tested in different materials by pressing in a single movement the metallic prototype against the surface of the board. The team came to realize that once the boards arrive to the drilling part of the manufacturing process already with coating, this new process would damage its surface and for that reason wouldn't do the job properly.

The other prototype was roughly made in order to explore the concept of easy assembling. What if, instead of having a complicated assembling process with different tools and materials, the furniture had LEGO® shaped junctions and the customer would have only to connect them (Figure 18)?

Fig. 18 – CFP table and shelf (sourced from team)

The team rapidly understood the strengths and limitations of the concept. In fact, the prototype demonstrated that a “click” junction that the user would only need to apply pressure, would create a good assembling experience. From the functional perspective, it had better results on the table stability wise because the gravity would force the legs to be attached to the top, but on shelves it would fail complete. The short contact between the junction of the “cabinet” and the junction of the shelf was not enough to hold the shelf in place because gravity would push in down.

CFP was the initial steps towards understanding different perspectives of the problem. It was the source of inspiration and learnings about both the requirements for the industrial process that would replace drilling and the impact of the functionality of the furniture when assembling.

The next prototype – CEP – was due to explore a different concept and validate ideas regarding an experience. The team had some insights from the company and the customer perspective collected earlier that indicated that there was a lack of customization particularly in cabinets with shelves that were presented to the client with predefined holes to place the shelves. Therefore, it was time to test how would users feel if they had a flexible and free way to place shelves according to their needs of placing different objects with different shapes and sizes (Figure 19).

Fig. 19 – CEP: Customizable shelves (sourced from team)

Fifteen people were invited to choose from different kinds of shelves and place them in a metal surface according to the objects they usually had at home. The test was recorded, and the team did observations on users' behaviour, their reactions and the way they would place the given shelves. After the test, there was a quick interview to explore further the way users felt and the reason for placing the shelves the way they did.

Some of them referred they placed the shelves according to the objects they normally have, others because of ergonomics, others simply wanted equidistant shelves and others were focusing on aesthetics. Some used big shelves, others small, some placed shelves vertically to divide the space, others would want to put clothes close to books. This flexibility for customizing had the potential to answer to all this variety of needs and desires but the team learned that having a blank canvas filled with different possibilities, oftentimes lead people to be stuck. It may be overwhelming to choose where to place the shelves having no restrictions.

Another challenge was to level the shelves, once there were no guidelines to make sure they were aligned, some users would spend a lot of time just trying to figure out if it was properly assembled.

The insights provided from both prototypes at this stage were emphasizing the need for empowering the user in having better assembling experiences that allowed to have different options of customization. So, the team decided to target shelves as their main concern for further developments. Which would be a challenge because every piece of furniture relies heavily on holes and, therefore, drilling, to be assembled and have proper stability.

The end of the quarter meant the wrapping up of all the learnings and collected information regarding the problem that was being explored. At that point, the team had built a relevant amount of knowledge of the internal environment of the factory and its processes, but also regarding customer experience. It was time to align the project and the team around well-defined requirements that would shape the future developments. Not only the team elaborated their own physical and functional requirements, but also, they should be able to correspond to the elements of the Democratic Design (Figure 20).

Fig. 20 - Democratic Design (sourced from IKEA)

The Democratic Design is a group of characteristics and elements that every product or new development must follow inside IKEA. Its dimensions are strongly connected to IKEA's strategy, ultimately putting in practice its vision of serving the "many people". The Democratic Design in deeply embedded in the company's culture and is a mean to apply its well-structured and though business model.

In the case of the ME310 project, it was a way to keep the team aligned with the company's values. At the end of the Fall Quarter was not the time to completely fulfil all the requirements because there was no solution yet, but it was important to orient the team for a certain path to help dealing with the ambiguity of the project. To reassure the following steps, the team elaborated a design vision that would lead the logic behind future prototypes – "To pursue an intuitive fixation system that gives customization freedom to the customer."

Each prototype and testing were closely followed by the corporate liaison that would visit PDF's facility regularly and meet with the team weekly or once every two weeks or was available by e-mail and phone. Also, a documentation with all the research, learnings, prototypes and tests was handed to the company. This was followed by a public presentation of the project for the companies and interested community.

During the quarter, besides the many visits that the team did to the IKEA Industry factory, the teaching team was also invited to deliver a workshop of Human-centred Design.

Workers from the different divisions of the technical department and middle management were gathered in teams to put in practice the methodology used in the project together with the students. In the words of Rui Coutinho, the ME310 Director, companies are eager to learn these methodologies that allow them to identify internal and external problems and provides a structured and systematic way to solve them in teams. That workshop gathered workers from different backgrounds and parts of the company to work on challenges identified by the top management and involved field research on the ground of the factory and interviews with colleagues as well as ideation and prototyping of the ideas. As noticed by one the participants, as they are constantly embedded in an industrial environment focused on efficiency and incremental adjustments to make a better use of time and resources, there's a lack a that kind of holistic, human-centred and agile thinking.

WINTER QUARTER

Winter Quarter was a key part of the whole project where divergence had its peak and important decisions were made in order to narrow choices and elect the final proof of concept that corresponded to the initial challenge. During this time several difference events happened to inspire, collect new knowledge and validate concepts.

January started with a trip that was usually out of the ME310 program, but it was done in Porto because of its huge impact on students and its skills acquisition, mindset building and creativity boosting. The European Organisation for Nuclear Research (CERN) has a structure called IdeaSquare that aims at "Connecting curious minds to accelerate ideas through collaboration, R&D prototyping, and experimental innovation" and is part of the Design Factory Global Network like Porto Design Factory. For that reason, the partnership among these two organisations provided a learning and inspirational environment for students during approximately one week.

Corporate liaisons were invited to join the group to learn about Arduino and robotics, which was an opportunity to Márcio Silva, the corporate liaison of the IKEA Industry project, make part. The challenge was that each team would build their own robot that could show three different emotions. The program consisted of lectures about the technology, field visits to the Dark Matter factory, the Large Hadron Collider (LHC), and talks with CERN scientists. That experience was due to challenge students to think ahead in the future and to be bold, in the 2017/2018 class, the projects were about the future of insurance, logistics, a smoke-free world, ecologic fashion. Dr. Markus Nordeberg, member of the Development and Innovation

Unit at CERN and one of the former responsible persons for the ATLAS project, inspired the students when visiting the larger particle accelerator in the world (LHC) by saying: “Ladies and gentlemen, it is my guess that this is the closest you will ever be to the beginning of our universe”.

That program was critical to acquire knowledge and practice on prototyping with different materials and technologies. Also, meeting other students from foreign universities and interacting with CERN scientists was a good source of inspiration to embrace a new phase of the project.

Another important trip defined the team’s alignment and vision. The students had the opportunity to do a Benchmarking Trip. It was due to visit other organisations in Europe that could bring important insights to the project, like companies, research-centres or specific events. IKEA Industry team decide to do three visits: SPACE10, IKEA of Sweden and the Stockholm Design Week.

SPACE10 is “a research and design lab on a mission to enable a better everyday life for the many people and planet” based in Copenhagen (Figure 21). Despite it being funded by IKEA, its projects aim at independently explore global and future trends and technologies, with a design-driven approach with a strong emphasis on sustainability. There, the team was inspired by projects related with the future of food, the change in the modern living spaces, innovative joineries for wood pieces, urban farming, and many others. When visiting the city and talking to young workers, the students came to realise that, in fact, housing was a relevant problem for people moving into the city. High prices and scarcity of houses was leading to small and shared living spaces.

Fig. 21 – SPACE10 projects: Recycled denim, urban farming, Japanese joineries (sourced from team)

Later, in the birthplace of IKEA, in the city of Älmhult, Sweden, the team had the chance to visit IKEA of Sweden, the epicentre for the global activity of IKEA. There were placed some of the most important innovation teams, engineers and designers that transmitted insightful information regarding how innovation is done inside the organisation. Follow the company's values, sustainability, global trends, quality products and improving lives of the many people, were some of the takeaways for the team to bring home. Also, embracing the company's culture, learning how they manage projects and how they consider the client as an important source of improvement, was enlightening for the future developments in the project.

Last visit took place in Stockholm for the Design Week, where the team was able to participate in the many activities and visit several showrooms in the city, but also to be part of the lightning and furniture fair happening at the same time (Figure 22). That was one of the biggest events of Scandinavian furniture, there were concentrated some of the most relevant manufacturers as well as designers and design studios presenting innovative furniture and home appliances.

Fig. 22 – Products displayed at the Stockholm Lightning Furniture Fair (sourced from team)

Research in primary and secondary sources was something that was present throughout the whole project. The team needed to constantly go back and forth because when adding new knowledge to the equation, that led always to building new perspectives on the problem and the possible solution itself. Because, at this stage, is time to explore deeper the problem and slowly start to have a clear view of the future of the project, the team collected the learnings from visits and external contributions and started working on setting its new understanding of the context.

One of the major topics in their heads was the changes in the living spaces that they heard about. They came to know that by 2050 there will be 9 billion people on Earth and 66% of them will be living in cities. If today is already a big challenge in major cities across the world, having a place to stay will be more and more difficult. Living spaces are getting smaller in order to accommodate more people and many students, young workers and sometimes families, have to share home. Also, people are moving all the time, they go to a different city or different house because of a better deal, So, the team realized that there was an opportunity for furniture to adapt to and enhance those changing living spaces. Furniture are pieces that give meaning and personality to every house and are crucial for each person to develop their daily activities in many ways. Therefore, those big changes needed a proportional respond from the furniture industry to meet people's needs and desires.

Their assumption was that furniture needs to be multifunctional and serve many different purposes, it should adapt to small spaces, occupying less room or allowing to be stored when not used, and for that should be able to be assembled and disassembled many times providing the same quality from the first to the last use.

Focusing on the challenge of providing versatile and reassembling furniture, the team continued to research about products that already fulfilled that demand or similar solutions that could inspire further developments.

Auxetic structures, artificial muscles, self-assembling particles from MIT, origami structures and furniture from IKEA itself that could already being on the path to answer that, like the EKET cube, were some of the topics that the team came across.

It was then time to come back to the roots of the methodology and prototype. The first deliverable of the quarter of the Dark Horse Prototype. It is the one that anyone bets because as less probability to be successful. As it was time to be bold and embrace risk, the team should choose the concept or idea that was less understood as feasible or viable. Even if that idea is in the "parking lot" of ideas since the beginning of the project, the Dark Horse is the time to build it and test. At this point it may happen one of two things with the corporate partner: the company may understand the methodology, trust the process and embrace the risky and unlike success, or it may try to position the team completely aligned with the firm's expectations and have a closer control of the path of the project. Companies' were all warned that this could happen, and the students were empowered to follow their research results and beliefs regarding the developments of the project.

The IKEA Industry team decided to explore two different concepts Live Furniture and Origami furniture. The first being farfetched in the sense of "what if furniture grows at your place?" and the other could bring the functionality and features needed to answer the trend of the small living spaces.

The Living Furniture relied on fast growing plants that would be shaped into a bench or table and could turn into garden furniture. A sustainable and environmentally friendly solution that could bring some personality to people's homes while not needing any special skill or tool to be assembled by the customer (Figure 23).

Fig. 23 – Living Furniture Prototype (sourced from team)

The second concept explored, the origami furniture, was thought to respond to the need of versatile furniture that could have different applications, offering customization options trough modularity and the ability to be stored easily when not used. The ancient Japanese art of origami is behind paper constructions with several different shapes and features allowing movement in some of the cases. The assumption was that it could be applied to furniture and enhance people's interaction with their furnishings while providing the functionality required in small living spaces.

The first iteration was an articulated wooden cube with duct tape allowing the movement of its faces (Fig. 24). The cubic shape was intended to provide the user the versatility to use it as a bench, a storage unit, a decorative appliance, or a small table.

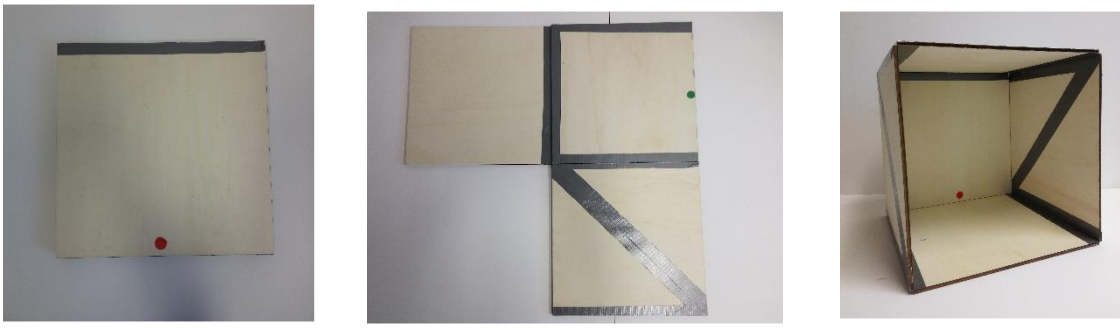

Fig. 24 – First Iteration Origami Cube (sourced from team)

Thought to increase versatility, the team decided also to build two other examples with two cubes and other with three cubes attached. This could be similar to the shape of some of the already existing IKEA furniture and could allow a rapidly assembling and desassembling. The DarkHorse Prototype ended with a pulic presentation and exposition in order to obtain users feedback and to validate some of the assumptions regarding the concept.

A both was build to simulate a house environment and show the potential applications of those products (Figure 25). That would place the visitors and the participants of the test in a real context and would provide an experience close to the one they could have at home assembling their own furniture.

Fig. 25 – DarkHorse Prototype Booth (sourced from team)

The tests were formally done with nine users that engaged with the prototypes, assembling and disassembling them while the team recorded on video, counted the time of use, watched the user's behaviour and collected different observations. At the end of the test there were some questions regading the experience provided, what the user felt during it and general opinion about the concept. While in exposition, the product was shown and tested by many other visitors and informal feedback was also collected.

The one cube version was the more popular among users because the other two iterations increased dramatically the time of assembly going from an average of 12.3s in the first versin to 3m31s in the third version. It was considered a relevant result because no instructions manual was provided which meant it was somehow intuitive for people to understand how to interact with the prototype. Generally, users were in favor of the one cube version: "if I want more cubes I could just buy and add the one I own already", one user said.

The team understood there was a security issue as some of the users got their fingers stuck as the prototype does not rely on indidividual parts but in a full structure all connected that opens and closes accordingly. Another learning led the team to realise the importance of the back piece for the cube to maintain its shape, support wheigh and maintain its stability. In general, users found the concept interesting because it was easy and lightweight enough to transport and store if not needed in a given moment. Its versatility as shown in the picture above, was a strong point for people that are really interested in furniture that serve multiple purposes.

During the presentation day, four members from IKEA Industry visited the booth and tested the prototypes. It was shown a great interest in the concept and it provoked an immidiate brainstorming between the visitors and the team about the next version of the prototype using the same materials the company applys and how could the duct tape, one of the key parts of the prototype, be replaced. There were some concerns regarding the industrialisation a product like that from the processes and equipments experts, but generally all the elements were aware that is was an initial concept meant to test improbable ideas. The interaction between the IKEA Industry members and the team led to new insights regaridng the mechanincs of future prototypes and it were drawn different hypothesis for a different folding of the prototype (Figure 26).

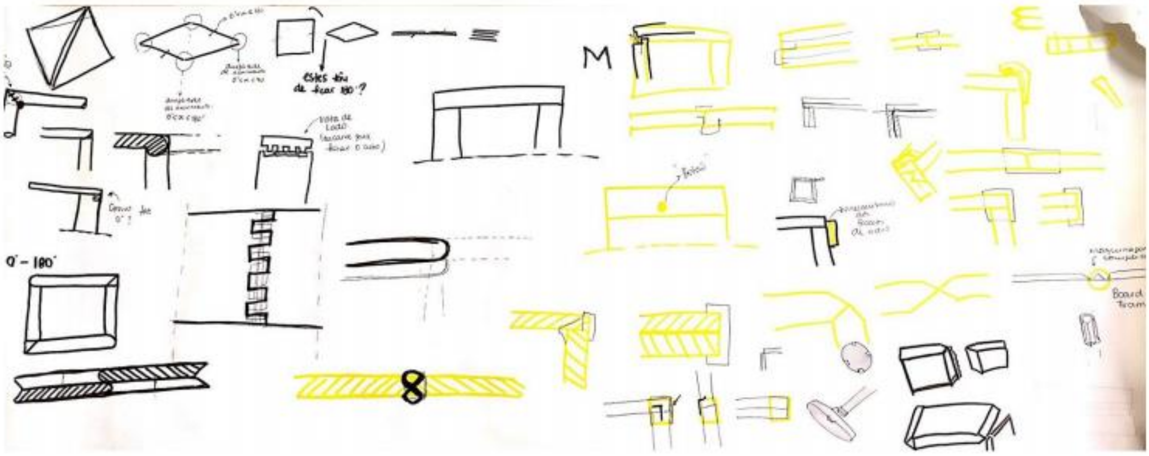

Fig. 26 – Sketches with hypothesis for future prototypes (sourced from team)

Approaching the peak of the divergent phase of the project, the team entered in the Funky Prototype mode. It was time to revise the different concepts explored until that moment and do a final push before deciding and commiting with a final idea.

Team dynamics is a relevant part of projects like ME310, the fact of having different backgrounds, cultutures and working remotly, may be an asset in some of the project's aspects, but it may be a difficult issue to overcome. Fastly going to the most critical part of the project where the team had to be fully aligned and oriented to the same goal, problems were raising since both teams were constantly communicating but exploring different concepts. A key part of the ME310 program are the mentorship sessions. The team had frequent meetings with a mentor specialist in team dynamics and project management. It was crucial to learn how to deal with the different setbacks of the project and to adapt communication in order to put every element of the team in the same page and commited.

The Funky Prototype was one step forward in the prototypes' complexity. Each phase of the project indicated an improvement of the robustness of the prototypes, the materials and the overall quality presented. Letting behind the rough and rapid prototypes to approach a moment where it would be more and more similar to real proof of concept.

The team decided to give a last opportunity to the moving shelves concept deeply explored in the Fall Quarter. Despite the DarkHorse concept had interesting feedback, the team felt the previous concept had a considerable potential and needed a better prototype to prove it (Figure 27).

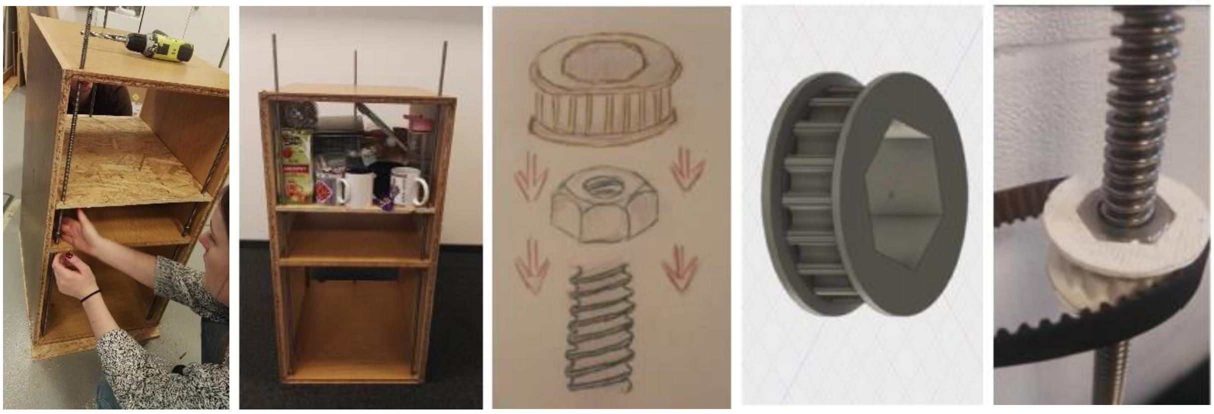

Fig. 27 – Shelf moving prototype (sourced from team)

This prototype was inspired in the 3D printer's system of moving the platform while printing an object. It consisted in a chipboard box with three screws positioned two at each side of the front and one in the back in the middle. The prototype relied on screwing a nut as shown in the first picture to move the shelf up or down with the system showed in the fifth picture. This prototype mitigated several of the issues raised in the prototyped before regarding the freedom do customize and adapt the product, the inherent way of lining the shelves and it did in a robust way. But the testing with users revealed some important insights. The team was truly believing the prototype and satisfied that it was a bold concept with a good execution that proved the idea, but it was time to ear the feedback and make decisions. Along the project the teaching advised: "Don't fall in love with your prototypes". This meant that the team shouldn't the feel the ownership of the ideas and rather should let the research and testing result be the guideline for path of the project.

The tests had good results in terms of acceptance, usability and from the functionality perspective. It could easily support 20kg worth of objects and adapt to its volume by adjusting the positioning of the shelves. But it all resumed to one question: Do they people really change the positioning of the shelves? The ten participants of the physical test and the 115 participants of an online survey led the team to understand that users position the shelves in their cabinets when they assemble it for the first time and don't feel the need to change it that often. 50% of the respondents said that they had never changed the positioning of the shelves or felt the need to since they assembled it for the first time and 34% said it may change it once a year.

At that moment, the team had to decide. Although it could be a concept with some potential, the users feedback didn't support a big demand for it and the students felt that the existing solution that IKEA already provided (multiple holes in the cabinets sides) could respond to the needs of the few that used it. Therefore, a descriptive and in-depth explanation of the concept was posted on the teams' documentations in case the company wish to explore the concept further in the future.

The convergent phase of the project had begun. To reorient every element of the team, the students decided to redefine the persona for whom they were building the solution (Figure 28). Previously it stayed open to whom they were developing the solution for: the ground worker of the factory, the manager or the final customer. It was clear, then, that the target should be the customer because he/she was the reason for the demand and the vision making a better everyday life for the many people, was about him/her.

PERSONA ID - customer

Adam Nowak
28 years old
Programmer
Warsaw
As a girlfriend

Pains:
- Lives in small and costly apartment
- Is not very organized with clothes and belongings
- Not able to have many people for dinner
- No tools in his small apartament

Needs:
- Versatile and affordable furniture
- Girlfriend likes well designed furniture
- Furniture that is easily assembled and

Fig. 28 – Persona Adam Nowak (sourced from team)

Understanding the pains and the needs of Adam, the team defined the origami furniture as the main concept to explore in future prototypes. That was the idea that corresponded to the requirements imposed by the company and by the persona now defined. The design vision was also stated in bold in the students' workspace in order to easily and visually remind them while working: "Simplify furniture to enhance living spaces". It was about empowering people to own their living spaces and make it comfortable and adapted to their needs.

That convergent moment was crucial for the team but also for the company. "Converging is very important to filter all the data generated and choose the path with bigger potential”, said Márcio Silva, the corporate liaison. At that team the company was aware of the development of the project and the different explorations, and some expectations were set regarding the shelves concept, which appealed to the firm’s team. “*But the goal for us to get into the ME310 project was to have an outside view of our business and come up with disruptive product ideas*”, continued Márcio, “*and my job as liaison was to balance both company’s and team expectations while empowering the students decision making*”. He strongly emphasized that it was extremely important to align the team with the company’s strategy and values, and once it was done, they should follow the process and the methodology to respond to the challenge. From the team side, students felt it was important to have regular contact with the company but that they should own the decisions during the project. The proximity and the understanding of the company about the process, made students feel that they could be bold but at the same time they were willing to take risk without the fear of failing.

Next stage was the Functional Prototype. It was a fast-moving endeavour to a quality, robust and close-to final artefact. The biggest challenge the team was facing with the origami concept was the material to replace the duct tape used in the DarkHorse prototype and define the mechanism to introduce it without using the drilling process.

The first iteration was due to experiment flexible and garment-like materials to allow the structure to open and close while keeping the 90º angles with the robustness and stability need for a piece of furniture (Figure 29).

Fig. 29 – First iteration of Functional prototype: Closed, open, 90º angle (sourced from team)

This prototype kept the mechanism of folding in the middle due to the joint seen in the “open” picture above. It would close by rotating down and overlap its faces (Figure 30).

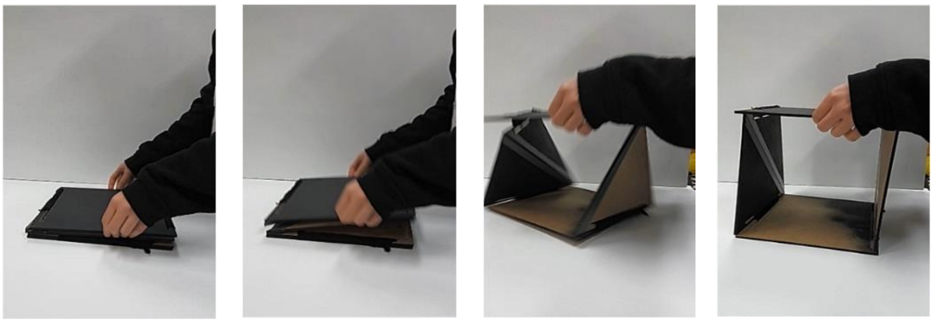

Fig. 30 – Folding mechanism of first iteration of the Functional Prototype (sourced from team)

As shown in the picture the mechanism was relying on the triangle faces of the both sides of the cube and the opening and closing was not a controlled and smooth movement as stated by the users. Also, the team assessed the difficulties of the potential introduction of the product with these specificities into production and realised that almost every piece in the factory is cut in a quadrangular shape. After this logic and the feedback received by the IKEA Industry elements in the DarkHorse exhibition, the team tried a different folding mechanism in which the triangular shapes are eliminated and there no rotation movement (Figure 31).

Fig. 31 – Second iteration of the Functional Prototype (sourced from team)

That version allowed a higher level of standardisation of the pieces and the building process. And the team continued focusing on improving the prototyped to achieve the resemblance to the IKEA models. The materials needed to be as similar as the ones IEKA Industry used already and the manufacturing process shouldn't need much changes regarding the capacity and equipment that the factory used at that time.

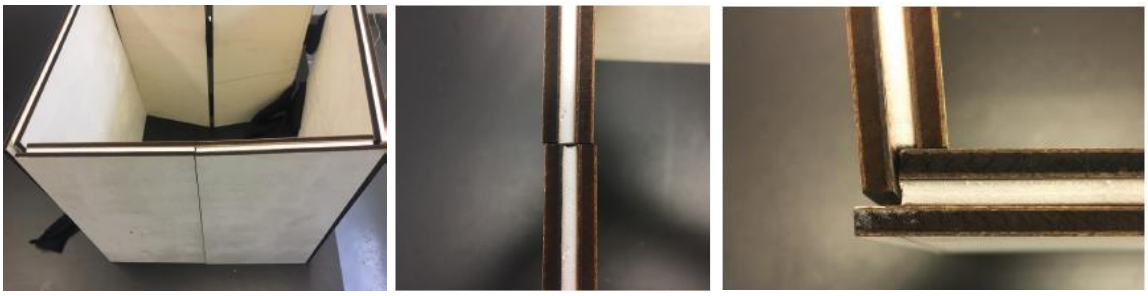

Fig. 32 – Third iteration of the Functional Prototype (sourced from team)

The students started using sandwich materials and the thickness of the pieces that IKEA Industry already uses in their manufacturing processes. With the advancing of the prototyping process, old problems were being solved but new ones appeared. How would the side pieces be connected in order to give stability to the product, was one of the questions. As seen in the second picture above, the two parts of the face couldn't just be placed on top of each other because it wouldn't give the need support. Also, the corners were a new challenge. How to maintain a 90º angle that is robust enough to handle manipulation by the user and weight but preserving the flexibility needed to assemble and disassemble? It was clear that the development was heading to a more technical and engineering-dependent approach to find a model that fitted all the requirements.

At the end of the Winter Quarter, when working on the final iteration of the prototype the Polish part of the team had the opportunity to join the Portuguese elements. Rita Gomes, one the students, reported that it was a crucial moment once the team was trying to be aligned and working in what was decided to be the final concept to pursue – "even with all the technology we have available to communicate like video calls, chat rooms and cloud documents, nothing compares to meet in person", she said.

Once again, the quarter finished with a presentation of the work done until than and the vision for the future. Now, together, the team was able to define a clear path for the next developments but with many open questions and problems to solve in order to build a quality proof of concept.

SPRING QUARTER

Spring Quarter was the end of the line of the project. Although the final concept was already defined, the prototyping activities of the last quarter showed even more challenges to overcome in order to turn it into an actual potential product. Some questions were raised:

- which material would be flexible and durable enough to connect all the pieces?
- which structural arrangements needed to be made to ensure stability?
- Was it a solution for that specific product or could it be applied in other products?

As Cláudia, one of the students said: *"At that point we were entering in a phase of the project when things started to become extremely technical and we couldn't handle it internally"*.

The team was able to contact several external specialists to help conceiving the product. One PhD candidate in materials engineering was a primary source for defining the material to be used to attach each piece of the cube together, the best suitable garment with durability, flexibility and low-cost to fulfil that need. Also, different engineers provided their vision of the concept. Having one of the elements of the team as a mechanical engineer provided the right interface to communicate about technical features. Mentors from Porto's Superior Institute of Engineering, from furniture factories, from IKEA Industry itself and other "makers" allowed the team to discuss about the several options available and which was the most viable in order to build a quality proof of concept.

The first prototype to be delivered was the Part X. A this point the team had to define and build the function, feature or structure that they considered the core in order to the prototype to execute what it was meant to do.

IKEA Industry team decided that the internal structure that would allow the cube to fold and unfold maintaining a stable position, was the most important characteristic to assure at this point. The requirements for this development were not needing the drilling process to be manufactured, allowing the 90º angles in a robust and stable way and providing a smooth disassembling of the furniture when needed. Through research, specialists' feedback and computerized tests, the students were able to go back to the workshop and start cutting the pieces of MDF, chipboard and honeycomb to achieve what would be one the last versions of the concept.

Fig. 33 – Three versions of the Part X prototype (sourced from team)

Three different versions were made for this prototype to validate both the production method and the shape of the joints. The first picture above shows all the pieces of a cube carefully crafted by a CNC machine. Until that point all the prototyping was done using basic wood saw machines to cut the chipboard and MDF materials which sometimes would not provide exact measurements allowing some tolerance that interfered in the prototype's performance. This test revealed that, in fact, accurate machining improved the pieces layout and the joining movement between them. Although it was successful test, the team knew that CNC technology was not suitable for IKEA Industry factory because it would mean a slower speed in the assembling line. But their machines were significantly more accurate and precise then the ones on PDF's workshop, therefore, it was a useful test to validate the technical drawings.

Next tests were due to validate the type of shape that the corner of 90º should have. The second picture shows flat corners that proved not to be the best solution because it didn't pass the stability of robustness tests. But, despite having a garment material joining the pieces and satisfying 90º corners, the cube wasn't answering properly when applied a lateral force because nothing in the structure was stopping the "closing" movement. In practice, when looking the third picture of the figure above, there was no part of the cube's structure that was preventing the vertical piece to come down and overlap the down piece when an external and lateral force was applied.

To mitigate that, it was created an internal structure all made by standardized pieces and the material already used by IKEA Industry as shown in Fig. 33. That picture shows the piece with the "male" part that would be attached to a "female" part by the garment material to provide stiffness and preventing the lateral movement.

But, when revised the potential manufacturing process at the factory, it wouldn't allow the finishing process of veneering the way IKEA Industry machines were able to do, which represented a major setback when implementing the solution.

Fig. 34 – Internal structure of the Part X prototype (sourced from team)

The third iteration of the prototype shows 45º cut pieces that perfectly match when the cube is assembled or open. According to the computerized tests in an engineering software, that was the most stable structure, and, in practice, it proved it right. The 45º cut corner presented in Fig. 32 and the internal structure presented in Fig. 33, culminated in the best suitable version of the prototype so far. It was answering the challenge by no having the drilling industrial process, the pieces had the most standardized sizes possible to facilitate its production and almost all materials were already used by IKEA Industry.

Fig. 35 – Folding movement of the Part X prototype (sourced from team)

The only material not yet used, was the ligament that would connect all the pieces together. The team explored materials like rubber and nylon with different densities and flexibility, but none responded satisfyingly. The solution the students found was a garment-based elastic material that provided the right flexibility and durability to allow several usages of the product and it was sold in large quantities providing lower-costs.

The the team realized that that mechanism could be applied in other types of furniture that IKEA had in its products' range. As many pieces of IKEA furniture were relying on 90º angles and flat surfaces, that could potentially be applied in bigger ones like the range Bestå and PAX (Figure 36). From that moment on the project was no longer about avoiding the drilling process neither a single product. The team made the statement of being developing a technology suitable for a variety of products, named as LÄNK Technology. The term came from the Swedish word for "link" or "connect" and as a technology it spread the horizon in terms of the potential applications of the concept.

Fig. 36 – PAX cabinet prototype with LÄNK Technology (sourced from team)

Until that moment, IKEA's furniture was not guaranteed of keeping the same quality after few times of assembling and disassembling. The eventual implementation of such concept meant new value to be delivered to the final customer.

The team had been meeting a business model specialist since the Winter Quarter, even before they knew the final idea, they were already learning about the importance of the solution to be integrated into the company's strategy and how to think about the viability of each of the concepts they would explore. A disruptive interpretation of the LÄNK Technology potential implementation could bring not only an improved and smooth experience of assembling for the final customer, reduce the burden of the drilling process inside the factory but also could change IKEA's business model. If furniture could keep its quality while being assembled and disassembled many times, that could mean a renting opportunity. Back to the persona defined earlier, young workers, students and families in urban areas move often, changing homes or moving abroad, which means always transporting or buying new furniture is a painful need. Giving the opportunity for those people to temporarily rent their furniture is a way to satisfy them, at the same time, profiting several times on the same product.

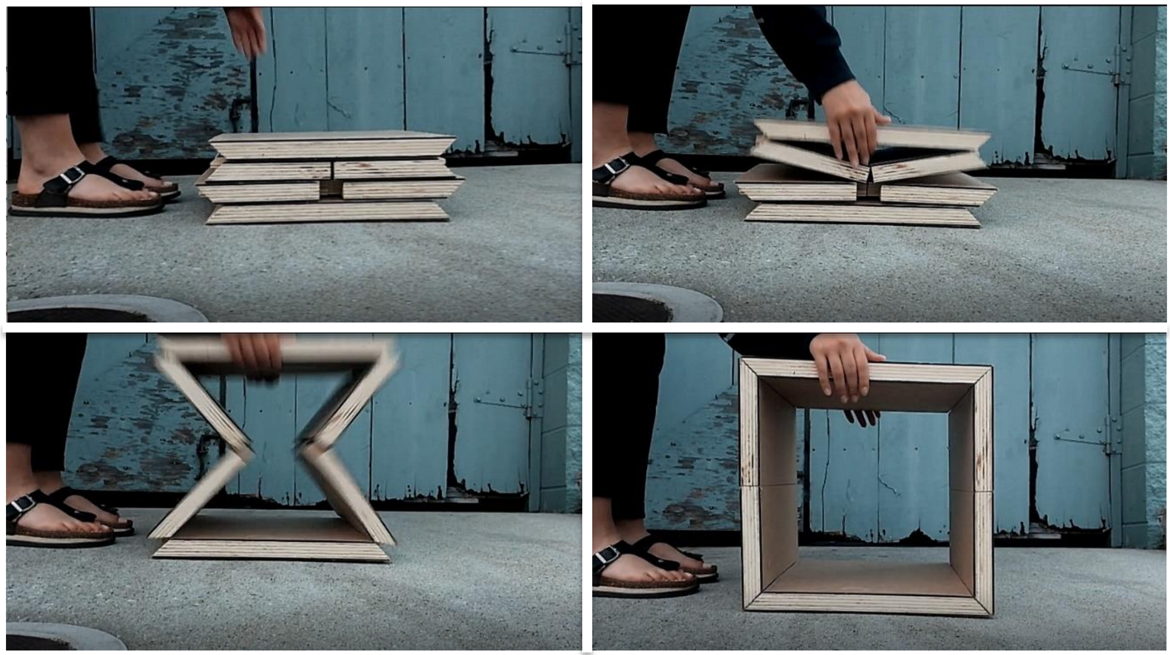

Fig. 37 – Assembling movement of the cube with LÄNK Technology (sourced from team)

The concept provided a seamless assembling experience without the need of any special skill or tool and it was a fast and intuitive way to get the furniture ready to use or store it (Figure 37).

At the final documentation delivered to the company, the team did an extensive exploration of the differences between the production techniques used by IKEA Industry

(BoS – board on style and BoF – Board on frame) and the one need for LÄNK Technology. Together with corporate liaison specialized in the factories' equipment's and assembling process, the students tried to present a process with the minimum changes possible in the current assembly line in order to improve the possibility to implement it.

Both the team and the company representatives were aware that the proof of concept had some limitations and a lot of room for improvement. And, as stated by Nuno Santos, head of the innovation department at IKEA Industry Portugal, that was the goal. To bring new insights, radical approaches to product innovation and challenging views of IKEA's business, manufacturing process and products in order to enrich internal knowledge and capabilities.

After the presentation of the project at downtown San Francisco, California, and the delivery of all due documents to the company. Márcio, the corporate liaison, explained that IKEA Industry Portugal and the PDC in Poland worked together during the project and all the knowledge produced was sent to the PDC for analysis and potential implementation. "IKEA produces a lot of innovation and not all of it is going straight to production, many of those ideas and concepts are kept in a portfolio until there's a need for it to be implemented", stated Márcio.

What begun by being an industrial challenge, led to a solution that could potentially disrupt how consumers interact with their furniture and generate a new revenue stream to a big brand.

4. Discussion

Transferring the scientific and technological knowledge and experience between university and industry is a relevant approach to improve innovation in the economy, therefore demonstrating the importance of University-Industry collaborations. Typically, both organisations have individual and common goals which impacts the way institutions interact, the underlaying motivation for this to occur is that type of collaboration is a mean to acquire the resources organisations lack (Airto, 2001).

The discussion will have an analysis of knowledge collected for the case to match with the goals set before. Generally, it aims at responding to the greater objective of understanding the specific context of the ME310 project between IKEA Industry and PDF and comparing the results to the theoretical framework explored before. The section 4.1 will investigate the motivations for the constitution of the UIC stated in the specific objective b). While 4.2 will dig into the objectives a) and c) regarding the potential and the outcomes of this partnership which were taken from both organisations. Last section, 4.3, will consider objectives d) and e) where the benefits of the relationship and the specificities of the innovation process inside IKEA Industry, will be explored.

This will align the initial theoretical framing with the investigation work by analysing the case study findings.

4.1 Motivations for the UIC

Porto Design Factory was created in 2014 as a co-creative platform to foster innovation inside Porto Polythecnic and for promoting alliances with industry partners through strategic relationships. IKEA with its Manufacturing Strategy 2020 directly stated the importance for the group to be open to external collaborations to acquire new knowledge and competencies. This represents the elaboration of an agenda related with innovation and inter-organisational collaboration from both sides which represents its strategic alignment (Perkmann, King, & Pavelin, 2011). Also, the collaboration enhances the permeability of the company borders to external inputs as it is a tendency nowadays and proved as a relevant strategy to acquire competitive advantage (Caraça et al, 2009).

ME310 is a program that may provide unexpected solutions for a problem previously identified by the corporate partner and relies heavily on continuous learning while the progress of the project is based on the Human-Centred Design methodology. The knowledge created through the way represents a critical asset in today's learning economy paradigm where corporations shift their position from sponsors to partners in order to absorb as much as possible (Jacob, Hellstrom, Adler & Norrgren, 2000). This is obvious when the linkage between both organisations is impersonated by a corporate liaison that aligns the team with the firms' strategy (Newberg & Dunn, 2002) but, at the same time, follows the work closely and absorbs the knowledge and the process.

Industry partners see UIC a potential opportunity to gain financial benefits through enhancing sales or introducing new products by benefiting from serendipitous results (George et al., 2002). This was strongly emphasized by Márcio Silva, stating that IKEA Industry wanted new insights and perspectives about their business, their processes and products. "We have a lot of internal knowledge because we've been doing this for ten years now, we understand our process and know our equipment, but we lack a fresh new vision which we knew we could get from ME310", said Márcio. The expectations of the company were not totally focused on financially benefit from the final proof of concept but that was a possibility to commercialize university-based technology (Siegel, Waldman & Link, 2003). But, contrary to some approaches to innovative endeavours (Cohen, Florida & Randazesse, 1998), IKEA Industry's innovation protection strategy doesn't rely on patenting or having full control of knowledge and technologies. The ME310 program handles all the knowledge generated to the company but it also promotes public presentations along the project, disclosing only the information allowed by the company.

IKEA Industry follows a very open strategy to protecting knowledge, as Nuno Santos said, "We want to be the first to go to market, not waste time protecting or hiding knowledge." The company believes that a short time-to-market is crucial to be the first exposing the solution to the customers and only in some specific cases, IKEA of Sweden decides to patent. The ME310 program also provides a privileged learning environment for all the individuals involved in the project. As the university is interested in doing (Santoro & Gopalakrishnan, 2000), it is a way to expose students to the industrial environment, knowledge and facilities of the corporate partners which could also represent employment opportunities for university's graduates (Lee & Win, 2004; Santoro & Betts, 2002). From the company's perspective, it may also be a way to discover talent and create a relationship with potential future employees (Ankrah, Burgess, Grimshaw, & Shaw, 2013). Which was a successful mission by the hiring of Rita Gomes, one the students, by IKEA Industry at the end of the ME310 project.

4.2. Potential and Outcomes of the Project

The ME310 program allows the university to fulfil its first mission – to teach. In today's competitiveness in the higher education landscape, universities must search for valuable propositions to attract students. Once the university teaches and trains students to embark on the job market with competitive skills and experiences, the practical exposure to industry's problems and immersion into the industrial environment, constitutes a learning opportunity (Santoro & Gopalakrishnan, 2000). Through the project, not only the students had the opportunity to face a technical problem from IKEA Industry, but they also had the opportunity to dig deep into it by doing several visits to the Portuguese facilities. To enrich the experience, the team also visited IKEA Industry Poland, the factories of Portuguese competitors and from other industries and stakeholders. That knowledge was completed with employees interviews which brought a deeper meaning to the understanding of the problem and the learning experience. This value proposition from the university is enhanced by partnering with relevant and well-known companies that might be appealing to students to work with (Mora-Valentin, 2000).

The engagement created through this relationship promotes the interaction between the company and the students which may be an opportunity for the university to have employ its graduates and, at the same, for the company to acquire talent (Cyert & Goodman, 1997). One of the students of the ME310 program, Rita Gomes, was hired after the ending of the project and she felt that it was a differentiable asset to be working with the company before for so long. "They could see the way I worked, my values and skills, but I could also immerse in the company's culture and understand its strategy which created a great fit", said Rita. Working with the company during the project made her prepared in terms of knowing the organization upfront, its values, processes, coworkers and facilities which boosted her onboarding process.

Universities seek for alternative funding sources besides public grants and once the ME310 program delivers value to very player involved with heavy emphasis on solving industry's problems, companies are willing to pay for the job done. This is particularly interesting for universities because it's less bureaucratic (Blumenthal, 2003) and it allows for enhancing the students learning experience as well as develop other activities. In the ME310 project its perceptible through opportunities to travel for benchmarking purposes, the specialized mentorship sessions available, and the materials and equipment to prototype.

It’s common for companies to seek the resolution of a technical problem (Kivleniece & Quelin, 2012) but IKEA Industry was not only looking for a straight solution the specific problem of the drilling industrial process, but also for a holistic view of its business in order to have fresh feedback and insights from it. Strongly enhanced by the Human-Centred Design methodology, it was possible to reach the final customer as the principal beneficiary of the final proof of concept. Although the problem was identified inside the factory, the systematic validation of the project process led to a user-focused solution that solved the technical problem at the same time.

The fact of having different students with different backgrounds, cultures and skills, and the inputs of several different mentors, provided the multidisciplinary environment that enriched the project from every feedback and input. That follows the vision of Sherwood, Butts, & Kacar (2004) stating that companies seek the variety of research expertise and inputs through the UIC.

The knowledge created and collected during the project was materialized in prototypes. That is commonly a major outcome from collaborative projects among universities and industry (Santoro & Gopalakrishnan, 2001). The ME310 project generated more than ten prototypes, some with several different iterations, each of them with its specific validation tests and results. That constitutes a relevant deliverable for IKA Industry to have as a first step for future developments. In the words of Márcio Silva “the outcomes of the project were delivered to the Product Development Centre (PDC) in Poland where they collect innovative concepts to further explore when needed”. All the documentation supporting the prototypes may also be a source of inspiration and knowledge about possible R&D paths and technical information to replicate those prototypes.

Prototyping is the way by which creative problem-solving happens. Before it, an ideation process must occur based on the previous findings about the problem. Diverging and converging provides the right environment to stretch the possibilities for solving the given problem. Inspirational moments like the visit to CERN and the Dark Horse prototype (Bushnell, Steber, Matta, Cutkosky & Leifer, 2013), are strategies to enhance and empower the creativity of students and allowing the problem space exploration “without” boundaries.

The final proof of concept or any idea explored before might constitute business opportunities for the company to introduce new products or solutions into their processes. A motivation for industry to collaborate with universities is to seek to commercialize its technologies for financial gains (Siegel, Waldman & Link, 2003). The LÄNK Technology as the most recognisable outcome of the project is suitable to be applied in different products and aim at eliminating drilling enhancing the manufacturing process which could implicate some level of impact in the company's performance if adopted in the future.

While the project ran, several workers from IKEA Industry were able to follow the team's progress and directly benefit from it. Training professionals is a valuable outcome of such partnerships (Santoro & Chakrabarti, 1999) and it can directly impact the people that contact with the team and the process as Márcio stated "I started including prototyping early in my next projects because I saw how the team did it and the importance of immediate validation. That had little costs for us and allowed me to test first before reaching suppliers of that service."

The participation of the company in the ME310 program is also an open door for getting international exposition and for networking opportunities with other universities and companies. Porto Design Factory is present in two different international networks DFGN and SUGAR and collaborates with several companies which come together in community events and projects public presentations. That may be a boost for initiating other inter-organisational projects with relevant impact in the firm's future (George et al., 2002).

Many tangible and intangible outcomes surged from the ME310 project, some are more explicit and measurable than others, but the results of this case study are generally aligned with the literature. Some dissonance may occur when discussing the protection of innovation to leverage competitive advantage in some industries, but a different approach was taken by IKEA Industry, in this case, by considering pioneering has the best strategy to approach the market. It was possible to identify outcomes that benefit the organisation, both the university and the company, but individual impact as well. Co-workers and students had different interventions in the project, but both had the opportunity to learn and develop competencies.

In a full sight of the knowledge transfer between organisations, the measurable inputs were three quarterly documentations (Fall, Winter and Spring) compiling the all the work developed by the team during the project. In their, besides the research about the furniture industry, the materials, alternative products, industrial process and market, were describing information regarding all the 10+ prototypes built and tested. The physical prototypes were made available for the company to take and use accordingly to their needs, as well as the testing results with the respective insights and learnings from each. Those were formally handed to IKEA Industry Portugal and PDC Poland, besides intermediary documentation made for specific themes, photos, videos of prototypes and testing, and other outputs produced by the team. Many outcomes were integrated in the form of learnings by the employees through the constant contact with PDF environment and the methodology, as well as the Human-Centred Design workshop given in the company's facilities.

The knowledge is part of the company's archive and it's available for different departments directly or indirectly involved in new product development to be used as needed.

4.3 Innovation Process and its Collaborative Potential

Although the project started by the deeply-rooted technical problem of "eliminating drilling from wood furniture mass manufacturing", the final proof of concept had a stronger focus on the final customer and it's needs. That's the fuel for the Human-Centred Design methodology that aims at solving the everyday problems putting the human desires in the centre of the process (Kelley, 2002). For IKEA, to "create a better everyday life for the many", means that the "many people" must be taken in consideration in every decision of the company. For innovation and new product development as well.

The team of students was able to extract the most relevant information from the factory and the manufacturing and translate that to leveraging a solution that would fit user's needs, which is enhanced by the tools and mindset of the Human-Centred Design by creating connections and empathy with the user (Giacomin, 2014). It was possible by understanding the need for a seamless assembling experience with no tools or guides, and the potential for the furniture to be assembled and disassembled several times, was not only a shot for individual user's pains, but also an answer to global demographic trends. Which is a relevant part of design as it must take in consideration society and its constant progress (Hauffe, 1998).

The tools of the Design Thinking that put in practice the human and user-centred vision, are understood as drivers for organisational culture and it may be a trigger for experiential learning, collaboration, risk taking and learning (Elsbach & Stigliani, 2018). In the words of Márcio Silva, the project had a relevant impact on his work process as he started to integrate prototyping in IKEA Industry's projects, which allowed them to validate assumptions early and subcontract services later in the projects.

The methodology as project management facilitator and its tools that bridge the gap between the design research team and the users, were extremely relevant for the project outcomes. The importance of continuously searching for validated assumptions and "getting beneath the surface" (Brown, 2008) introduces a new concept into new product development once human-centredness aims at enabling humans through well design technological interfaces (Krippendorf, 2004) and enhance lives.

CONCLUSION

University-Industry collaborations are a relevant interface for two organisations with different missions to complement themselves turning the innovation process more efficient by sharing resources and knowledge.

The Learning Economy demands that companies continuously search for the state-of-the art technologies and market insights to stay ahead of its competition, and universities have also de desire of understanding what is happening inside companies to provide better learning experiences to its students. The potential of this collaboration reaches a high when students work in a real context solving a real problem through immersion and employee and customer engagement.

Both organisations had individual and common motivations for establishing the partnership. IKEA Industry needed an outside view of its business and processes, PDF wanted to enhance its teaching offers by providing a problem-based program, and both were eager to contribute to society by developing new technologies.

All the stakeholders and individuals involved in the project had potential benefits taken from the outcomes of the project. As a knowledge absorption and creation tool, the ME310 program brought insights regarding technological breakthroughs, market information and the validation of an innovation methodology, Human-Centred Design. The creative approach to problem-solving and the positioning of humans in the centre of the problem, provided the opportunity to solve a technical problem while enhancing the customer experience. Also, the contact between the company's employees and the team working process, led to the implementation of early prototyping in internal projects.

The project was a relevant contribution to IKEA Industry's innovation portfolio by integrating more knowledge it their database that will feed future new product development efforts or inspire new outcomes. As a first mover, IKEA's general strategy is to fast deliver value to its customers rather than over develop and protect its products.

Many other examples of University-Industry occur but the ME310 has its particularities that makes it a valuable win-win collaboration for the ones involved. Future investigations may deepen the understanding of the innovation's adoption and long-term impact of such projects in company's culture and process.

The limitations of this work are bonded with both the initial theoretical exploration and the resources used for building the case study. There was an effort for bringing the most relevant references globally that investigate the innovation field and produce insightful publications, but other valuable works might be out of the ones collected for this work. Also, the results of the case were biased towards the interviews perspective and knowledge of the different subjects studied. Having the perspective of the Product Development Centre (Poland) workers in the case, could bring valuable insights due to their impact in the group's innovation process.

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Appendix 1 – Interview Guide Nuno Santos

Interviewee: Nuno Santos - IKEA Industry's Portugal Innovation Department Director

About IKEA and IKEA Industry:

1. What are the internal sources of innovation of IKEA Industry?
2. What are the external sources?
3. Which fields of investigation is IKEA Industry exploring right now?
4. What is IKEA's general strategy to protect its innovation outcomes?
5. Which innovation methods does IKEA Industry use?

ME310 related questions:

6. What are the motivations for the development of an innovation project together with a University?
7. What does an ME310 project brings differently from other interorganizational collaborations?
8. Who owns the outcomes of the project?
9. How were the outcomes of the project protected?
10. What have the company done with the outcomes of the project so far?
11. How were the outcomes protected?
12. Which are the benefits of this partnership for the organization? Which impact had aside the final proof of concept?
13. Which are the difficulties/challenges?
14. What is the importance of the Human-Centred Design methodology in the project?

Appendix 2 – Interview Guide Rui Coutinho

Interviewee: Prof. Rui Coutinho, Porto Design Factory Director (2014-2018)

1. What is the purpose of ME310? What are the motivations for the development of an innovation project together with a corporate partner?
2. Which are the challenges of establishing and maintaining the partnership?
3. How is innovation protected in ME310 (patents, utility models,...)?
4. How is intellectual property manage in ME310 projects?
5. How is knowledge and technology transferred between the partners?
6. What is the role of the university in this partnership?
   6.1 What is the expected role of the corporate partner?
7. Which benefits does this partnership bring for the university?
   7.1 And for the students?
8. What is the importance of the Human-Centred Design methodology in the project?
9. What is the importance of a diverse and distributed team of students for the project?

Appendix 3 – Interview Guide Márcio Silva

Interviewee: Dr. Márcio Silva (Corporate Liaison)

1. Why did IKEA Industry enroll in ME310?
2. What is, in your opinion, the importance of co-creation projects between university and industry?
3. How do you see the role of the corporate liaison in this partnership? What is its importance?
4. How much time have you dedicated to the project?
5. Did the project have any relevant outcomes for your professional life? If yes, which ones?
6. What impact did the project have in the company?
7. Which were the difficulties/challenges felt during the project?

Appendix 4 – Interview Guide Team Members

Interviewee: Team members - Cláudia Legoinha and Rita Gomes

1. Why did you enroll in the ME310 program?
2. How much time did you dedicate to the project?
3. What are benefits of having a corporate partner in the educational program?
4. Which difficulties/challenges did you face during the project?
5. Which were the outcomes of the project for your professional career?
6. What was the importance of the Human-Centred Design methodology in the project?
7. How do see the role of the corporate liaison in the project?

Annexe 1 – Briefing Document from IKEA Industry

ME310 SUGAR | Porto Design Factory + Warsaw Design Factory

ELIMINATING DRILLING IN WOOD FURNITURE MASS MANUFACTURING

INITIAL BRIEFING
24/10/2017

MAIN THEME	ELIMINATING DRILLING IN WOOD FURNITURE MASS MANUFACTURING
CHALLENGE	How might we make IKEA Industry's workplace better by eliminating all drilling from the manufacture of wood furniture and simultaneously enhancing the IKEA's furniture functionality?
BACKGROUND	Nowadays, there are limitations from drills that only have fixed positions which do not allow flexibility to easily move elements positioning like shelves in the furniture. On top, drilling process is the slowest in the furniture manufacturing, it is also a process that creates a lot of dust, very time consuming the set-up, bottleneck of the factory and any error do not allow the furniture assembly.
CHALLENGE DESCRIPTION	Work in a field where IKEA doesn't have a solution yet. When we find a solution, it can go into massive production quickly, revolutionize the furniture offer and make its production leaner. A challenge that if we succeed, it will create a better everyday life for the many customers and also make the workplace better (free of dust) for our co-workers.A main design restraint is that furniture needs to maintain the positioning of elements in 90º