FARLEY MILLANO DE MENDONÇA FERNANDES

# **Design Thinking Canvas Autonomus:** addressing Little Design Up-Front through conceptual design automation

Thesis presented at Departamento *d*Design, Centro de Artes e Comunicação from Universidade Federal de Pernambuco (UFPE), as requirement for obtaining doctorate degree, under supervision of Prof. André Neves, PhD and Prof. Ernesto Vilar, PhD.

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FARLEY MILLANO DE MENDONÇA FERNANDES

**DESIGN AUTOMATION DESIGN THINKING CANVAS AUTONOMUS: ADDRESSING LITTLE DESIGN UP-FRONT THROUGH CONCEPTUAL DESIGN AUTOMATION**

Dissertação ou Tese apresentada ao Programa de Pós-Graduação em Design da Universidade Federal de Pernambuco, como requisito parcial para a obtenção do título de Doutor em Design.

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A Alana e Inês, minha casa.

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# RESUMO

A nossa pesquisa explora a possibilidade de se aplicar agentes inteligentes para automatizar ou apoiar parte da atividade de design e avaliar se este tipo de ferramenta pode desempenhar tão bem quanto um humano faria. Portanto, apresentamos a metodologia de design thinking chamada Design Thinking Canvas e seu aplicativo correspondente chamado Design Thinking Canvas Autonomus que possui funcionalidades que permitem automatizar ou apoiar a criação de conceitos, o que significa que três variações metodológicas são possíveis: off-line (completamente humano), apoiado (humano ajudado por computador) e automatizada (completamente automática). A justificativa para explorar tal abordagem vem do contexto da atividade de design ser executada em projetos ágeis. Entre os temas mais proeminentes nesta junção, Little Design Up-Front se destaca como um dos mais importantes. Ele corresponde à desafiadora necessidade do agile em definir um objetivo claro para o projeto, enquanto evita desperdícios desnecessários no longo prazo – uma grande quantidade de designs ou especificações sendo descartados, por exemplo. De forma a testar se as variações metodológicas do Design Thinking Canvas poderiam ajudar a endereçar tal necessidade, foram desenvolvidos dois estudos. Um primeiro que testa a eficácia da ferramenta Autonomus em si em gerar conceitos design automaticamente em comparação a um humano usando o mesmo aplicativo. E um segundo estudo para avaliar produtos reais criados sob as mesmas variações metodológicas de design. Os resultados mostraram que, na maioria dos casos, não houve diferença estatisticamente significante entre variações do Design Thinking Canvas para os designs gerados por máquina e humanos. As maiores diferenças encontradas foram no fator criativo-inovador a favor das versões off-line ou apoiado e no fator evolução técnica a favor dos designs automatizados. Isso estabelece um novo quadro de referência para projetos ágeis e para o campo do design como um todo, já que o custo e o esforço para executar o Autonomus é significativamente menor do que um processo totalmente humano.



Palavras-chave: metodologia de design. design thinking. Agile. Automação. little design up-front

# ABSTRACT

Our research explores the possibility of using intelligent agents to automate or assist part of the design activity and evaluate if this kind of tool can perform as good as a human designer would. Thus, we present a design thinking methodology called Design Thinking Canvas and its corresponding app called Design Thinking Canvas Autonomus that has features that can assist or automates the creation of design concepts, meaning three methodological variations are possible: offline, assisted and automated. The justification to explore such approach comes from the context of design activity being executed within agile projects. From the most prominent themes of this conjunction, Little Design Up-Front stands outs as one of the most important. It corresponds to agile's challenging need of defining a clear objective for the project, while avoiding unnecessary waste in the long run at the same time – large amount of designs being discarded in the future, for example. In order to test if Design Thinking Canvas methodological variations could help addressing this need, we developed two studies. One, having an experiment to evaluate the efficacy of the Autonomus tool itself in automatically generating design concepts in comparison to a human using the same app. And a second study, comprising two different experiments and project domains, to evaluate real products created under such design methodological variations. The results showed that, in most cases, there was not a statistically significant difference between Design Thinking Canvas variations on machine and human-generated designs. The main difference encountered was on creative-innovative factors in favor of assisted or offline versions of the methodology and on technological evaluation in favor of the automated one. It establishes a new frame of reference for agile projects and implications for Design field as a whole, as the cost and effort to execute Autonomus is significantly lower than a totally human process.

Keywords: design methodology. design thinking. Agile. Automation. little design up-front

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SUMMARY

# 1 INTRODUCTION

The process of "new product development" must integrate activities from its conception until its marketing, containing among other things, a process of design (CROSS, 2000; TURNER, 1985). That said, what might be the implications for design when the management model of its activities shall be based on short and highly iterative cycles aimed at innovation, as in the case of agile methodologies? A need for a dynamic model for design activity that can quickly respond to tactics changes is reported by Reid and colleagues (REID *et al.*, 2000). On an immediate and initial analysis, agile paradigm with the principles postulated by Agile Manifesto (BECK *et al.*, 2001) can supposedly help addressing this issue. Moreover, it is interesting to note that the integration of design with agile methodologies opens up a perspective to develop an evolutionary product where success is measured not only by software testing, but also by flexibly incorporating proper changes to software across time due to the impossibility of predicting user behavior at the beginning of the project (FERREIRA; NOBLE; BIDDLE, 2007a).

While traditional project management methods, such as PMBOK, focus more on complex tools and processes (PROJECT MANAGEMENT INSTITUTE, 2013), the mindset brought by agile methodologies puts more effort on teamwork and flexibility (BECK *et al.*, 2001). For example, the framework proposed by Scrum (an agile representative for project management) brings an iterative way for new products development aiming primarily at speed and flexibility (TAKEUCHI; NONAKA, 1986). It arises from the need for innovation in companies where, consequently, variability between planning and execution for a given problem can be very large (Schwaber, 2004). Iterative models of project development work with short-term planning, allowing the team to concentrate their efforts on developing and understanding of the problem (SOMMERVILLE, 2007).

Design as a practice is usually conducted in a highly iterative way (BERENDS *et al.*, 2011), agile methodologies in turn also stimulate an iterative behavior, but despite this overall synergy, it is also necessary to explore their conflicts as opportunities for scientific contributions. For example, it is interesting to note that Agile offer flexibility in favor of the "client" (KANE, 2003), but often this role in a design project does not corresponds necessarily to the "user" of a product (FRYE; INGE, 2013; SILVA, T. *et al.*, 2011). As we will further detail, there are several opportunities to be explored within agile context for design field, but our focus will be specifically located on a theme called Little Design Up-Front.

## 1.1 RESEARCH PROBLEM

Among the most relevant topics in the conjunction of design activity and agile paradigm, currently one of the foremost concerns is Little Design Up-front, whereby the design work should be conducted in small portions throughout the project, especially in the beginning of the project (ADIKARI, Sisira; MCDONALD, Craig; CAMPBELL, John, 2009; SILVA, T. *et al.*, 2011). This is a conflicting issue, because, on the one hand, design classically expects to generate all or most of its specifications early in the project (BAXTER, M., 2000; CROSS, 2000; PAHL; BEITZ, 2013; SOHAIB; KHAN, 2010). On the other hand, the expectation of agile methodologies with Little Design Up-Front is to minimize waste generation during project execution – large amount of designs being changed in the future –, so it is expected that all of product development processes, including design activities, to be conducted in an emerging way.

Through the analysis of recent studies concerning design's activity in an agile environment (BRHEL *et al.*, 2015; INAYAT *et al.*, 2014; JURCA; HELLMANN; MAURER, 2014; SALAH; PAIGE, R. F.; CAIRNS, 2014; SALVADOR; NAKASONE; POW-SANG, 2014; SILVA, T. *et al.*, 2011; SOHAIB; KHAN, 2010), we can see that the paradigm of agile development finds a stronger connection with only a few areas within design field, such as: Usability or Interaction Design. Given the historical connection of agile methodologies to software development (BECK *et al.*, 2001), it is natural to expect this specific focus inside design. However, it is important to expand this relationship, especially when considering the process of "new product development" as a whole, an effort that can naturally integrate teams of various practices or functions, not only software teams. This argument is endorsed by the fact that 36% of companies adopting Scrum, an example of agile methodology, are already located in areas not linked to technology (KIM, D., 2013). Besides excluding several stakeholders in the process, the immediate consequence of having only this narrower design focus is the occurrence of little to no discussion on the steps of problem definition or "product discovery" (BRHEL *et al.*, 2015). That is to say, to explore the possibility of using multidisciplinary perspectives (or design approach that stimulates so, in our case) that delves more strongly in conceptual stages and still allows multidisciplinary collaboration as expected by agile methodologies.

Therefore, our take for guiding design practice within agile context will be through Design Thinking (DORST, 2011; JOHANSSON-SKÖLDBERG; WOODILLA; ÇETINKAYA, 2013; KIMBELL, 2011). Besides being an underexplored design segment within agile, we chose Design Thinking as it shows some parallels with this paradigm, such as being action-oriented, working iteratively and employing multidisciplinary teams (FRYE; INGE, 2013). This integration might be especially prolific for design as agile paradigm has been expanding its borders to other areas not related to software development as stated previously. But as important as acknowledging their synergies, it is also relevant to observe their internal conflicts. Researchers already gave some perspective on that by showing, for example, that agile practices might limit divergent thinking or that Design Thinking might be perceived as producing waste for agile context (FRYE; INGE, 2013; LINDBERG *et al.*, 2012; LINDBERG; MEINEL; WAGNER, 2011). As design thinking representative, our research will adapt and apply Design Thinking Canvas methodology (NEVES, 2014) for agile project contexts. This methodology has been developed across several works by GDRlab research group at Federal University of Pernambuco.

Considering all the arguments presented, it is clearly necessary to widen the understanding and update the connection of design with agile product development scenario, especially with regard to the ability to integrate multidisciplinary practices and deepen the product discovery phase in the light of organizations' contextual restrictions (BRHEL *et al.*, 2015). Also, such new perspective must have Little Design Up-Front as its main target. Thus, our contribution will be guided towards evaluating if using an automated design thinking approach (Design Thinking Canvas Autonomus) that employs artificial intelligence for conceptual design creation can help agile teams in addressing LDUF. Moreover, can computational machines alone be as effective and efficient as humans while proposing design concepts?

## 1.2 HYPOTHESIS

### *1.2.1 General hypothesis*

Design Thinking Canvas Autonomus is as effective as humans while generating conceptual designs.

### *1.2.2 Specific hypothesis*

1. Design Thinking Canvas Autonomus is as creative and innovative as humans while generating conceptual designs and products.
2. Design Thinking Canvas Autonomus generates concepts and products as technically evolved, suitable and viable as the ones generated by human beings.

3. Design Thinking Canvas Autonomus generates products that can be considered Minimum Viable Product as much as the ones generated by human beings.
4. Design Thinking Canvas Autonomus generates products that is flexible for evolution as the ones generated by human beings.

## 1.3 RESEARCH OBJECTIVES

### *1.3.1 General objective*

This research aims to methodically address Little Design Up-Front by proposing and evaluating a computationally assisted version of Design Thinking Canvas methodology for agile projects.

### *1.3.2 Specific objectives*

1. Review the literature regarding Little Design Up-Front to analyze its latest developments.
2. Review the literature regarding design activity support by computational tools, especially for automation.
3. Present Design Thinking Canvas methodology and Design Thinking Canvas Autonomus app.
4. Evaluate Design Thinking Canvas Autonomus automation efficacy against human-generated designs under Creativity, Suitability, Viability and Feasibility criteria.
5. Compare agile teams using all Design Thinking Canvas methodological variations while developing their products.

## 1.4 JUSTIFICATION

Agile paradigm has been notoriously relevant since the 2000s when Agile Manifesto was launched by software experts (BECK *et al.*, 2001). It marked a step towards understanding the implications of developing products through the exploitation of fluidity and flexibility and not by classic stage-gate industrial paradigm. The borders for the application of agile paradigm have been expanded from a software centric approach to other organizational sectors as well (KIM, D., 2013).

As part of this process, design as a discipline and field of practice also have to adapt itself in order to be insert within such context. One of the main concerns for design within agile context is the need for later commitments, called Little Design Up-Front (ADIKARI, Sisira; MCDONALD, Craig; CAMPBELL, John, 2009; BRHEL *et al.*, 2015; SILVA, T. *et al.*, 2011; SILVA, T. S., 2012; SOHAIB; KHAN, 2010), which clashes from a more traditional view that design practice must create all specifications for a project beforehand (CROSS, 2000). This new perspective of conducting design activity in an emergent manner is endorsed by Norman and Stappers' view that designers must be involved not only in the beginning but also during product development itself as many sociotechnical complexities arises across time (NORMAN; STAPPERS, 2016). In a wider sense, this can certainly impact not only design practice, but also design as a discipline, including its own learning processes and pervasiveness to other domains.

Regarding the theme of Little Design Up-Front is possible to observe that there is yet to be defined a way to handle it through design methods, this is the point of departure for our research. Our approach to do so will be through computational assistance for conceptual stages of design process, as most of the technological tools for designers are mostly located on more advanced stages of product development.

## 1.5 MOTIVATION

Regarding design activity, computational tools to support it have been around for quite some time. The most popular set of such tools is what is called CAD (computer-aided design) tools which are usually applied in advanced stages to help materialization of products and its representations when the scope of the project is already fairly defined. The difficulty for technological tools to delve into conceptual stages in design process comes from the need for human intervention on these or "there is a real challenge in this field to open up to more exploration based tools and processes" (PESCHL; FUNDNEIDER, 2014). It requires a constant exploration of the problem space and creative inputs to define an initial solution. In this paper, we set out to investigate whether an intelligent system can help in diminishing this gap.

The need to properly address Little Design Up-Front is especially relevant for startup companies as they usually lack resources to make big investments. Issues related to Little Design Up-Front, such as lack of up-front planning or unpredictability, are among the greatest worries for companies adopting agile (MELO *et al.*, 2013). This is why our contribution will be guided towards the creation of software apps (applications) by these companies.

From a scientific perspective, another motivation for our research is the fact that most of the related works regarding design practice within agile projects do so by means of Usability or Interaction Design, which gives little space for more conceptual design stages, such as requirements definition or product discovery (SALVADOR; NAKASONE; POW-SANG, 2014). So, in order to provide some balance to this fact, we are going to handle Little Design Up-Front through the means of a computationally assisted design thinking methodology, as this will bring some novelty for design as a scientific discipline.

From a personal perspective, the author of this thesis is deeply interested in agile practice context, due to his professional background of digital product manager. This will certainly make the overall research approach and its results mostly oriented to practical benefits for designers located in such context of practice. Consequently, being relevant to organizational settings as a whole.

## 1.6 SUMMARY OF THE DOCUMENT

The second chapter stands as the theoretical background of our research, which will provide the intended context for design activity and the characterization for design field as related to management activity, especially agile paradigm. Next, in the third chapter we present our object of study which is represented by Design Thinking Canvas methodology and its technological variations introduced by Design Thinking Canvas Autonomus.

Next, we lay out methodological aspects of our research in order to present the steps taken towards our scientific contribution for Design as a scientific discipline. We specifically present a sequence of methods for our two studies, one for conceptual design evaluations form two different variations of Design Thinking Canvas methodology, and a second study focused on evaluating products generated from such variations.

The next chapter presents the operationalization of the methods defined in chapter 4. Meaning that all procedures executed and partial results from study 1 and 2 are presented and discussed. In the sixth chapter, we present and discuss the overall results from a unified analysis of the two studies. Finally, on the last and seventh chapter, will be given a summary of our research with its conclusions, contributions and possible future works.

# 2 THEORETICAL FRAMEWORK

In this chapter, we introduce the context of agile methodologies as it sets some new implications for design activity. Also, it is shown an overall distribution and several characteristics of design activities and also frame design (the discipline) as an essential tool for organizational management. Finally, we present the adopted theoretical framework for handling the intended research problem. This all set the specific foundational basis for what will be further discussed along the work.

## 2.1 AGILE AS PROJECT SETTING FOR DESIGN ACTIVITY

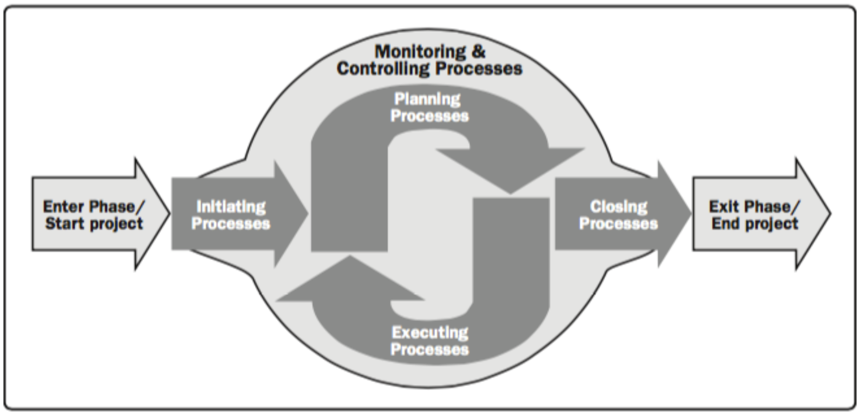
This section starts with a discussion over theoretical views of project management in order to identify implications of complementary perspectives (traditional versus agile) on the topic. The goal is to provide foundation for this work regarding project management, and locate which paradigms it will be based when choosing Agile/Scrum as a tool and theoretical representative for design activity context. Later, a literature review focused on Little Design Up-Front is conducted to unveil the latest developments from the state of the art in order to justify and give context to our own research's contributions.

### *2.1.1 Theoretical models of project management*

In order to understand the context in which design activity happens, it is important to discuss the implications of adopting agile and non-agile methodologies as this can lead to several advantages or constraints to be considered. For the sake of such comparison, we will focus on two of the main representatives for both worlds: PMBOK and Scrum.

PMBOK (PROJECT MANAGEMENT INSTITUTE, 2013), as a traditional project management methodology, structures its 47 process in groups (Initiation, Planning, Executing, Monitoring and Controlling, and Closing) (see figure 1). The idea is to give a greater focus in project life cycle as a temporary effort. In addition, the separation of processes in areas (Integration, Scope, Time, Cost, Quality, Human Resources, Communications, Risk and Procurement) aims to cover all aspects involving a project. This is extremely important for large-scale projects, since it may involve large teams, a long list of risks, large budgets, long-term procurements, etc. So they employ, beforehand, a significant number of processes and techniques for planning and controlling all of these variables.

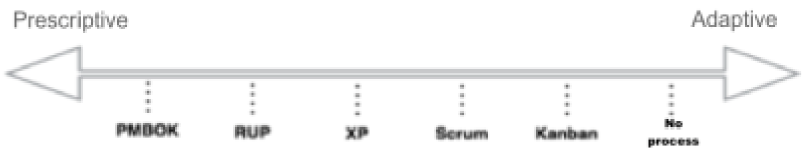
Figure 1 – PMBOK's process groups




Source: (PROJECT MANAGEMENT INSTITUTE, 2013)

As it is mostly focused in project life cycle and planning, PMBOK as management structure can turn out to be less flexible in terms of adaptability to certain contexts. This is especially conflicting when it comes to digital products that must constantly update themselves over time. For this reason, it can be said that traditional project management methodologies, such as PMBOK, are more prescriptive (more processes and predefined rules) that the adaptive (KNIBERG; SKARIN, 2010) (see figure 2).

Figure 2 – Relative scale for prescription / adaptation of management framework




Source: adapted from (KNIBERG; SKARIN, 2010)

Regarding specifically software projects, Agile Manifesto was launched in 2001 (BECK *et al.*, 2001) with the objective to create a single vision and compile the main principles from several methodologies aimed at bringing more flexibility to product development. Agile vision contrasts waterfall's one (BALAJI; MURUGAIYAN, 2012) in the sense that products should now be iteratively developed through constant costumer involvement and feedback. This way, developers can harness better understanding of the problem under consideration to unveil opportunities across time. Since then, several agile methodologies have been largely developed and adopted, with Scrum (SCHWABER, 2004) and Extreme Programming (BECK, 2000) being the most notable ones. Nowadays, the application of agile mindset is being expanded beyond tech-centered organizations, for example, 67% of companies already adopts Scrum outside IT departments to some extent (SCRUM ALLIANCE, 2016).

Much has been published about agile methodologies, but very few formalism for its concept has been established. This was the basic motivation that led Conforto et. al (CONFORTO *et al.*, 2016) to devise a formal conceptualization for what it means to be agile. They combined literature review with frame semantic analysis methods to come up with core concepts for agile, resulting in the following structure:

Table 1 – Agile formal definition through frame semantic elements

| Entity | Event | Degree | Trigger | Purpose | Circumstance |
|---|---|---|---|---|---|
| Project team | Ability to change the project plan | Quickly | Response to customer<br>Stakeholders needs<br>Market change<br>Technology change | Achieve better project performance<br>Achieve better product performance | Innovative and dynamic project environment |

Source: (CONFORTO et al., 2016)

From their analysis, what Conforto et. al could found for agile was:

- Agility is an ability more than a result of a method, which makes it practice-agnostic and consequently more expansible to other contexts than IT.
- It depends mostly from the combination of: rapidly responding to project planning changes and active user involvement in development process.
- Most of the definitions for agile coming from project management researches was found to be sometimes incomplete, redundant or unclear.

In order to find the implications from constructing and adopting new theoretical models of project management, Lauri Koskela conducted several studies and collaborations with other authors on the subject (BALLARD; KOSKELA, L., 1998; KOSKELA, L.; BALLARD, 2006; KOSKELA, L.; HOWELL, G., 2002a, 2002b; KOSKELA, L. J., 2011; ROOKE *et al.*, 2012). His finding was that many of the limitations or problems encountered in the traditional methodologies of project management comes from its own theoretical formatting in terms of the adopted models. For such analysis, the author uses PMBOK methodology as a starting point for comparison, which is suitable for our objectives.

To execute a theoretical analysis of project management, Koskela separates it into two main areas: project theory and management theory. From this segmentation, PMBOK's project theory would be based on "transformation theory", according to which production should be seen as the transformation of inputs into outputs (KOSKELA, L.; HOWELL, G., 2002b; STARR, 1964). This theory adopts a more static view of the project where tasks are considered independent, uncertainties should be minimized and time is not regarded as a production attribute.

According to Koskela's classification, the theory of management is, in turn, broken down into three parts: planning theory, execution theory and control theory (main groups of the PMBOK processes). Regarding the planning theory, Koskela argues that the PMBOK brings the vision of "management as planning", according to which in every organization there is clearly a management part and an executing part, and attributes management actions as being primarily responsible for organizational results, which quite often does not reflect well an organizational setting (Johnston & Brennan, 1996 apud L. Koskela & Howell, 2002b). In turn, the theory of execution is based on "job dispatch" (EMERSON, 1911; KOSKELA, L.; HOWELL, G., 2002b) consisting of the interface between the plan and the action, where a decision is taken and a resource is allocated for execution (KOSKELA, L.; HOWELL, G., 2002a). This theory assumes the ready availability and complete understanding by resources at the time to perform a specific task. Finally, the control theory is based on the "thermostat" model, whereby the performance is constantly measured during the output of a process and compared to a reference value and any variance to that is considered for adjustments (HOFSTEDE, 1978; KOSKELA, L.; HOWELL, G., 2002b). This view believes that processes are continuous flows and that correction occurs easily via a control variable (KOSKELA, L.; HOWELL, G., 2002a).

Compared to this classic theoretical framework built based on PMBOK, Koskela also did a research of new theoretical models and how they complement each other (KOSKELA, L.; HOWELL, G., 2002a). In addition, the author also shows how these other theoretical models fit into most current project management methodologies, including Scrum.

Table 2 – Scrum's theories

| **Scrum** | | |
|---|---|---|
| **Area** | | **Theory** |
| **Project** | | - Flow<br>- Value generation |
| **Management** | *Planning* | - Management as organizing<br>- Management as planning |
| | *Execution* | - Language / action perspective |
| | *Control* | - Scientific experiment<br>- Thermostat |

Source: (KOSKELA, L.; HOWELL, G., 2002a)

In Scrum, the project theory is based on the vision of "flow", according to this model, uncertainty and time within production are considered as a dynamic central aspect of project context (GILBRETH, F. B.; GILBRETH, L. M., 1922; KOSKELA, L.; HOWELL, G., 2002b). In addition to that, this model promotes the elimination of waste which facilitates the reduction of variability and cycle time. Another model that supports Scrum's project theory is "value generation", according to which the value should be constantly added from customer's point of view (KOSKELA, L.; HOWELL, G., 2002b; SHEWHART, 1931). This is constructed by taking the premise that the desired requirements by the project customer are not necessarily static and fully known at outset, but that this process of discovery should be evolutionary. That is, the costumer takes a strong centrality in the project through this model.

With regard to management theory in Scrum, the author again dismembers it in: planning, execution and control. Firstly, for planning, the model adopted by this methodology is represented by a fusion of "management as planning" (previously detailed in PMBOK's analysis) and "management as organizing". In this second theory it is understood that all human action is located and reflects previous actions (JOHNSTON, Robert B.; BRENNAN, 1996; JOHNSTON, Robert Bruce, 1995; KOSKELA, L.; HOWELL, G., 2002b). With that, it brings a non-hierarchical approach, which gives greater autonomy to the team with regard to communication, planning and performance within a project.

Project execution on Scrum brings the "language / action perspective" theory that focuses on commitment as a tool for coordinating organizational work (KOSKELA, L.;

HOWELL, G., 2002b; WINOGRAD; FLORES, 1986). The team itself is the one responsible for delivering, instead of having a central control entity that issues commands for resources (in Scrum these roles are merged), a two-way communication based on individual and team commitment is stimulated within projects.

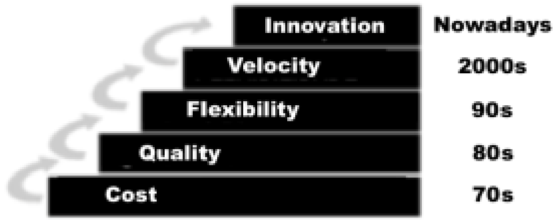
Finally, control in Scrum is based on two models: "thermostat" (also previously detailed in PMBOK’s analysis) at the organizational level and the "scientific experiment" to the levels of: cycle (named as “sprints” in Scrum) and daily meeting (Daily Scrum) (KOSKELA, L.; HOWELL, G., 2002b; SHEWHART; DEMING, 1939). The theoretical model of the thermostat is also used, but only at the organizational level this time, in order to review and adjust the project after each cycle (e.g. costs incurred or deadlines). The model of scientific experiment in turn brings a vision of learning and continuous improvement. This way, the operational sequence (specification, production and quality assessment) should be viewed as steps of a scientific method, namely: hypothesis formulation, conducting experiments and hypothesis testing, respectively. All this happening cyclically in sprints and daily tasks levels.

A summarized view of such theoretical orientations is presented on table 2.

### *2.1.2 Scrum*

Our research experimental part had Scrum as its agile framework (further detailed in experiment chapter), so we will detail its internal functioning to give proper background. Scrum serves to manage new products development and had their foundations laid by Nonaka & Takeuchi (TAKEUCHI; NONAKA, 1986). They could map it within the operations of some companies in a context of constant demand for innovation. They were able to observe how design and development processes of new products which were essentially flexible and fast in the organizations under analysis. These factors enabled a better time-to-market for their products in really competitive markets. In fact, this need still seems to be relevant due to a higher demand for innovation as a strategic focus for companies, as illustrated in the figure below (CABRAL, 2008; IBIE, 2004):

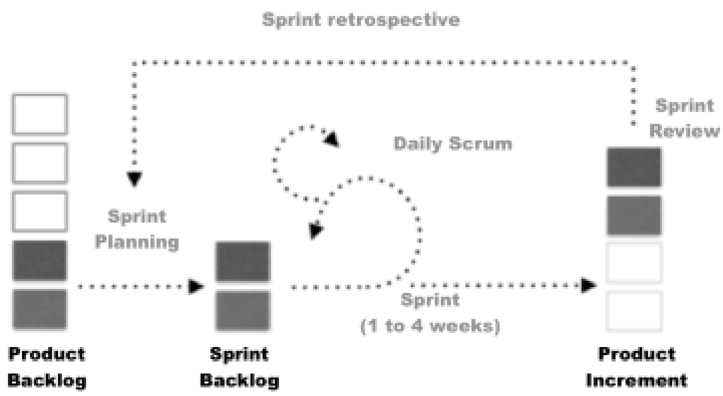
Figure 3 – Strategic focus for opportunities identification




Source: (CABRAL, 2008; IBIE, 2004)

According to Schwaber (SCHWABER, 2004): "Scrum is not a prescriptive process; it doesn't describe what to do in every circumstance. Scrum is used for complex work in which it is impossible to predict everything that will occur." As shown previously, Scrum's lower prescription allows it to be adaptable to a wide variety of contexts - project size or scope unpredictability, for example. Scrum operates through the interaction of a self-managing multidisciplinary team that works from start to finish on a project, rather than segmented by department or sequential phases (TAKEUCHI; NONAKA, 1986). Its iterations' cycles are called Sprints and have other steps at its beginning and end. These events are sometimes called "ceremonies" and its execution is detailed below (SCHWABER; BEEDLE, 2002):

Figure 4 – Scrum's ceremonies (grey) and artefacts (black)




Source: created by the author

Scrum starts at the Sprint Planning, where a prioritized product backlog (evolutionary list of all requirements to be implemented) is estimated by the whole team. The selected items for a given sprint become sprint backlog and developed collaboratively by the team during this cycle. During this execution, daily scrums are also conducted, they consist of quick catch-up meetings (usually 10 minutes long), so that each member share individual progress, interpersonal alignments and impediments to their tasks.

A key feature of Scrum is that it works incrementally (continuous delivery flow) and limits the batch of work through a fixed duration for its sprints (usually lasting 4 weeks) throughout the entire project. This enables the product to be delivered regularly and steadily. The natural consequence is that this functioning also enables the team to collect feedback and generate faster value for project stakeholders. At the same time, by not predicting a complete planning for the project at outset, Scrum allows new requirements for the product to be created or modified over time in its product backlog.

At the end of each cycle (Sprint), two ceremonies are conducted: sprint review and sprint retrospective. The review ceremony stands for the collective presentation of the deliverable produced to all stakeholders to reap feedback and determine what will be done next in the sprint (new requirements, for example). After the review, the team must perform the sprint retrospective, when everyone should self-evaluate and improve their current working process, so that any optimization is already incorporated into the next cycle (SCHWABER; BEEDLE, 2002).

This modus operandi favors our choice of Scrum as agile framework for setting project context in our work, since it stands for an adaptive model – inclusive to multidisciplinary methods and teams during its cycles – and less inherently focused on software practices, such as Extreme Programming (BECK, 2000), which is another relevant agile representative.

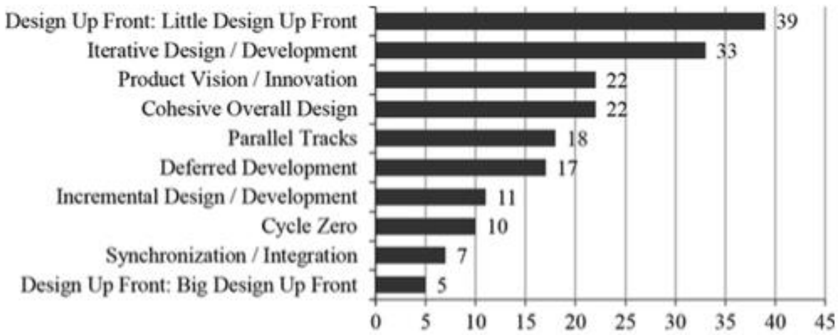
### *2.1.3 Related works: Little Design Up-Front as a need within agile setting*

The conjoint context of design and agile paradigm as a research topic is highly relevant and prevailing, especially considering the discussion of one of its most prominent subthemes, which is the Little Design Up-Front (LDUF), introduced previously. For this reason, we need to review and discuss what is the current state of related works so that the specific contribution for Design field of our research is differentiated from others and a justification for our work is developed.

“Limited up-front design effort is particularly necessary to provide a consistent and cohesive user interface and navigation structure as it supports designers in finding a suitable design concept from the very beginning”, according to Bhrel et. al (BRHEL *et al.*, 2015).

Albeit being conflicting with a more traditional view of design's activity disposition, the theme of Little Design Up-Front is very relevant with regard to the implementation of design activities in agile context, as can be seen by the occurrences ranking in Figure 5 (a similar relevance shown by (SILVA, T. *et al.*, 2011; SOHAIB; KHAN, 2010)).

Figure 5 - Frequency of processes' mentions within agile projects




Source: (BRHEL et al., 2015)

Waste within digital product development can come in many variations, like "unnecessarily complex solutions", "building the wrong feature or product" or even "extraneous cognitive load" on team members (SEDANO; RALPH; PÉRAIRE, 2017). Moreover, for example, integrating User Experience into agile projects can also introduce several challenges, like: lack of design focus and the need to modularize of design activities into cycles being among the most referenced in literature (NADIKATTU, 2016). Thus, the issue of Little Design Up-Front is indeed relevant and there is a need for new contributions, because on the one hand there are some researchers reporting that there should not be room for much design at the outset (LINDVALL *et al.*, 2002; UNGAR; WHITE, 2008), while others making the case where a certain amount of design should be conducted earlier in the project (FERREIRA; NOBLE; BIDDLE, 2007a, 2007b), and others bringing a combination of the two, with design going a cycle ahead of development (SY, 2007). This lack of overall standardization seems to be the main motivation behind Salah and colleagues' initiative (SALAH; PAIGE, R.; CAIRNS, 2016) to come up with a maturity model regarding the integration of user-centered design within agile projects. This way, organization can perform a self-assessment to evaluate their own capacity in absorbing these practices.

In any case, the creation of granular, smaller requirements helps to better derivate activities from larger system modules (DÜCHTING; ZIMMERMANN; NEBE, 2007) and emergent requirements is a widely used practice in agile requirement engineering (ALAM *et al.*, 2017). As agile methodologies exercises a more practical approach to project execution (e.g. Agile Manifesto's focus on "working product" delivery, instead of extensive documentation (BECK *et al.*, 2001)), requirement management have been expanded to include a specific set of methods being labeled as Agile Requirements (ALAM *et al.*, 2017). This is essential as big, early plans are usually discarded or at least modified (ERNST *et al.*, 2014). Even non-functional requirements are positively affected by the practice of LDUF (ALSAQAF; DANEVA; WIERINGA, 2017). For instance, system usability is normally considered a type of non-functional requirement, Adikari and colleagues (ADIKARI, Sisira; MCDONALD, Craig; CAMPBELL, John, 2009) reported that the incorporation of Little Design Up-Front in development process results better on this perspective – products that are easier to use and learn, and require less support when in use. Requirements prioritization is an important input for Little Design Up-Front, and in this aspect, agile methodologies relies mostly on business value to do so (SILVA, Ana *et al.*, 2017), this can be problematic as other aspects should also be considered on their overall impact on the project (INAYAT *et al.*, 2014).

The amount of time and effort to be spent on Little Design Up-Front is an issue presented as open by Silva (SILVA, T. S., 2012) and similarly by Gunst (GUNST, 2012), as there are many ways to handle this question, one can interpret it as a need for processes optimization (design's one, in our case). In this aspect, it indeed seems relevant to study the issue of design processes integration with the agile environment, as a bad execution on that is one of the reasons that prevents Little Design Up-Front to be implemented (JURCA; HELLMANN; MAURER, 2014). One of the advantages of interleaving design and development activities, as in agile environment, is the possibility of proposing and making changes to the software as result of users feedback, but to do so designers must practice lightweight methods (SILVA DA SILVA; SELBACH SILVEIRA; MAURER, 2015). These authors go on in stating that agile environment led to the emergence of new design methods for usability.

Ferreira and colleagues report that a certain amount of design must be conducted at the beginning of the project and that it should be primarily guided by the amount of risk introduced to the project (FERREIRA; NOBLE; BIDDLE, 2007b), but they do not report on this decision-making process in much detail. Adikari and colleagues conducted an experiment to test specifically the inclusion of Little Design Up-Front in the context of a project, which revealed the benefits indicated previously, but again it is not informed in detail the methods to achieve it (ADIKARI, S.; MCDONALD, C.; CAMPBELL, J., 2013; ADIKARI, Sisira; MCDONALD, Craig; CAMPBELL, John, 2009). Salah and colleagues discussed two issues closely related to Little Design Up-Front: "lack of time for upfront design" and "design chunking" (SALAH; PAIGE, R. F.; CAIRNS, 2014), which can possibly hint some of this issue's pain points. These authors report on the importance of having some time ahead of development for design investigations and the difficulty of balancing designers' inherent holistic view against the need of modularization for incremental development in agile projects. Some authors report the practice of “Sprint 0” (design in one cycle ahead of development activites) as a help towards Little Design Up-Front (such as (SALAH; PAIGE, R. F.; CAIRNS, 2014; SY, 2007)), but it might introduce a mini-waterfall process which is certainly counter-productive for an agile context (JOUHTIMÄKI; OTHERS, 2015).

Silva identified Design Up-Front as having two variations: on release or sprint levels, the first deals with product research and the latter with product design itself (SILVA, T. S., 2012). Similarly, Brhel and colleagues suggested that a more structured way of handling Little Design Up-Front is by separating the stages of product "discovery" and "creation" (BRHEL *et al.*, 2015). Furthermore, unlike Ferreira (FERREIRA; NOBLE; BIDDLE, 2007b), Brhel and colleagues report that there is still no clear definition on this subject with regard to the appropriate level of effort to be devoted for it in the project. This position is similar to Salah and colleagues' one on design chunking (SALAH; PAIGE, R. F.; CAIRNS, 2014). The argument is in turn partially corroborated by Silva and colleagues (SILVA, T. *et al.*, 2011) by reporting that most of the studies reviewed by them do not state in detail the methods or techniques used to handle Little Design Up-Front directly, limited to bringing only some examples of related efforts but that does not specifically address it. Interestingly, later on his PhD thesis, this same author (Silva) seems to have synthetized his view on the issue, stating that there is still not a clear definition of techniques or artifact used to address Little Design Up-Front (SILVA, T. S., 2012). On their review, Bhrel and colleagues codified Little Design Up-Front and design methods in different categories and made no relation between them (BRHEL *et al.*, 2015). While Little Design Up-Front is important, the integration of design activities with the development ones still needs to be well addressed (SOHAIB; KHAN, 2010).

From all this, the first opportunity of scientific collaboration we identified is to separate clearly the concept of what would be Little Design Up-Front for design's perspective as a discipline, since the term "design" can also refer to architectural aspects of software (CARBON *et al.*, 2006; FERREIRA; NOBLE; BIDDLE, 2007b; LINDVALL *et al.*, 2002). Sometimes it is hard to differentiate one another in reviewing related works, as the context (agile software development) and its terms are fairly the same or close. The second and most important opportunity is to develop a methodical way to establish the minimum and adequate definition for a product to be developed in agile context. That is to say, what is the ideal balance of Little Design Up-Front in the light of contextual organizational aspects, as suggested by Brhel and colleagues (BRHEL *et al.*, 2015).

The usage of Design Thinking in our research is backed by the fact that agile methodologies by themselves usually do not provide solid means of handling user requirements, specially the elicitation phase (DÜCHTING; ZIMMERMANN; NEBE, 2007). Although these authors suggest the integration Usability practices in order to address it, these practices are mostly suited for handling user interfaces and not overall conceptual product definitions, which might not even need interfaces, for instance. This is clearly evident as Salvador and colleagues (SALVADOR; NAKASONE; POW-SANG, 2014) report that most of the studies regarding Usability in agile projects are located on more advanced project phases, such as implementation (50%), whereas only a few are done in more conceptual ones, such as requirements (22%). We hope that using Design Thinking as design's perspective on our study helps to overcome this fact and weigh more heavily on conceptual stages. Moreover, Design Thinking application can positively contribute to project management practice towards innovation (see table 3), this happens mostly in three dimensions: exploration, stakeholder involvement and strategizing (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016).

Adikari et. al (ADIKARI, Sisira; MCDONALD, Craig; CAMPBELL, John, 2013) already proposed a high level framework for using Design Thinking as means for integrating user experience and usability to agile context, but the integration is not explained in much detail neither seems to be validated. A much closer example to our research is the one developed by Frye and Inge which sought to analyze the implications of Design Thinking in an agile environment through product owners' perspective (FRYE; INGE, 2013). Their research was more general than ours and found that Design Thinking, although perceived as generating waste, was also stated as responsible for increasing product effectiveness in minimizing rework. Other works lightly related to ours were the ones developed by Lindberg and colleagues, where they performed a comparative analysis of Design Thinking and the software development's perspectives - implications, similarities and differences among them (LINDBERG *et al.*, 2012; LINDBERG; MEINEL; WAGNER, 2011). Although Frye and Inges' and Lindberg's researches deal with related practices and certainly can provide some guidance to our research, they have different goals and focus in comparison.

Our research relates more to what Brhel and colleagues suggested as "product discovery" (BRHEL *et al.*, 2015), and what it specifically intends to address with Design Thinking practice is the existence of "weak requirements at start", which is an issue related to gradual detailing of requirements, as demanded by Little Design Up-Front (BJARNASON; WNUK; REGNELL, 2011). At the same time, it is also important to acknowledge that "managing product vision" is the second most mentioned challenge to user experience field within agile, due to the need to fit its activities in this different functioning (KUUSINEN, 2015).

If it means to start with small project definitions and commitments, our challenge is to make them effective as well. Through an extensive literature review, Werder and colleagues (WERDER; ZOBEL; MAEDCHE, 2016) summarized a list of design requirements and related principles regarding software product discovery process (see table 4). It closely relates to and validates our research objectives, even though their proposed methodology to address these principles differs a lot from ours due to different focus and background of each work.

Our final take on LDUF's state of practice, goes similar to the one of Kieffer and colleagues (KIEFFER; GHOUTI; MACQ, 2017), as they state that:

> "[…] there are, at least to the extent of our knowledge, no acknowledged procedures or practical guidelines regarding the effort to put into initial up-front analysis and design activities, and uncertainty remains regarding their duration".

This statement and all previously discussed results show that, although the theme has an extensive relevance for design activity, there is still very little consolidation on how to address it. Thus, our research has a specific take on that by making use of a relatively mature Design Thinking methodology (detailed in the next chapter), which has been expanded to incorporate technological support for designers to make it more efficient and effective towards Little Design Up-Front.

Table 3 – Design Thinking contributions to project management for each dimension

| Design Thinking impact on project management | |
|---|---|
| **Propositions** | **Dimensions** |
| Exploration projects or projects characterized by high uncertainty are wicked problems similar to those for which design thinking is relevant. | *Exploration* |
| Through its focus on learning, hypothesis identification, and articulation regarding the problem before searching for solutions, as well as its emphasis on experimentation, design thinking can contribute to the exploratory dimension of projects. | |
| Through its tools supporting deep data collection and idea generation that encourage managers to work with multiple options such as generating and evaluating multiple hypotheses and moving multiple solutions into active testing, design thinking represents an effective and practical approach to manage the exploratory dimension of projects. | |
| Based on its strong and wide user-centered orientation, design thinking can help address stakeholder management within the exploration project phase. | *Stakeholder involvement* |
| Through the use of tools that enable rich and multiple interactions with users (personae) and favor empathy, design thinking represents an effective and practical approach for achieving stake- holder identification and involvement in exploration projects. | |
| By emphasizing the diversity of the team involved in the design process well beyond the designers, the artifacts, and the space they share, design thinking represents an effective and practical approach for managing stakeholder interactions in exploration projects. | |
| By starting with a problem definition phase, design thinking can contribute to the articulation of the project strategy. | *Strategizing* |
| Through its tools and the attitudes, it promotes, design thinking ensures that multiple options will be considered and tested. Because of this, it represents an effective and practical approach for defining and articulating the project strategy. | |
| Design thinking tools provide a firm-level capitalization vehicle that enables the reuse of knowledge from one project to another. | |
| Design thinking complements the traditional project management analytical and functional perspective by emphasizing the meaning of the innovative project. By doing so, it makes an important contribution to strategy orientation and formulation. | |

Source: (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016)

Table 4 – Product discovery requirements and related principles

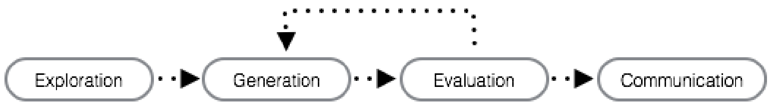
| Software Product Discovery | |
|---|---|
| **Design requirements** | **Design Principles** |
| Articulate early activities that improve the software product development environment | *Product context, goals, purposes and key requirements require clarification in order to improve product success.* |
| Collect initial product ideas | |
| Form a product vision | |
| Extract users' needs for pragmatic and hedonic qualities. | |
| Improve the adoption of practices for researching users' needs | *A method of Software Product Discovery should provide methods to research and integrate specific users' needs and demands into the software product design and development process in order to the product's usability and user experience.* |
| Properly document and record user requirements as a basis for further design and development activities | |
| Enable the integration of user requirements and user-centered practices into further design and development activities | |
| Enable the product team to develop a unified understanding of the product | *A method of Software Product Discovery should guide a diverse team of specialists to develop a unified understanding of the product and its importance.* |
| Enable the product team to master both, development maturity and creative thinking | |
| Assure management support for the product team | |
| Clearly distinguish different roles and their responsibilities for the product team | |

Source: (WERDER; ZOBEL; MAEDCHE, 2016)

## 2.2 DESIGN STAGES, STRATEGIES AND ACTIVITIES TYPES

Over time, problems addressed by designers became sufficiently complex to a level that they could not be treated in a merely intuitive way or solely based on previous knowledge, which led to the development of the first methodologies in the 1960s (BÜRDEK, 2005). Design methodologies usually tend to present themselves by contemplating the analysis-synthesis-evaluation cycle (CROSS, 2000; JONES, 1963). Nigel Cross has developed a generic model for addressing descriptively the stages of design process (CROSS, 2000):

Figure 6 – Stages of Design process




Source: adapted from (CROSS, 2000)

At high level, this methodological model for design process describes that a project must first investigate the problem space (Exploration), which is usually poorly defined, so at this stage, the dyad problem-solution evolves as a single set in terms of understanding for the designer. Next, alternatives are generated (Generation), which is denoted to be the most creative stage of the process because its result is an initial proposal for the problem being treated. The next step, Evaluation, acts synergistically with its previous because it is when the alternatives are selected against a certain design criteria and eventually refined by means of a new generation cycle. Finally, we have Communication, which corresponds to delivery of the final product of design process. This delivery should manifest itself in a high degree of detail, which can take several forms, such as drawings, so there is a perfect understanding for others involved in the project. Nigel Cross' model exposed in figure 6 can serve as the reference for standardizing the terminology to be used in naming the stages of the design process as a whole. It clearly denotes the stage where the project is located to deepen and enable a proper analysis.

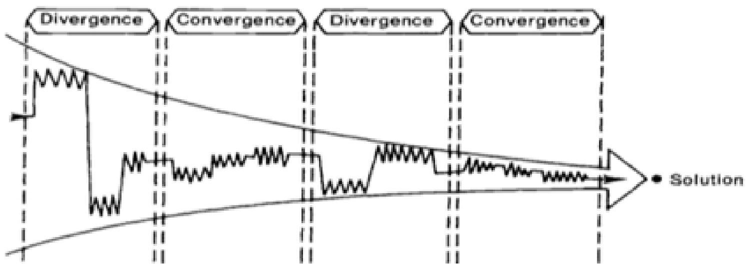
Regarding strategic emphasis on designers' activity, Kruger and Cross have identified four types of orientation (KRUGER; CROSS, 2006):

- Problem oriented: focuses in problem definition so that a solution can be found.
- Solution oriented: less focus on problem definition and major focus on generating solutions along with the problem reframing to match the solution being developed.
- Information oriented: higher focus on obtaining information from external sources to develop a solution based on that.

- Knowledge oriented: minimal usage of external sources and higher usage of personal previous knowledge for solution development.

These strategic orientations stands for the approach taken by designers during project development. Moreover, it is also known that the activity of a designer is extremely iterative, varying cyclically between two types: convergence and divergence. The former represents the creative exploration phase and the later the phase of integrating / testing solutions (BERENDS *et al.*, 2011). Overall, Cross visualizes the activity of a designer standing in a process convergent, amidst convergent and divergent smaller cycles (CROSS, 2000) (see figure 7).

Figure 7 – General distribution of Design process




Source: (CROSS, 2000)

While characterizing Design Management, Gorb (GORB, 1986) also presents this area as a "funnel" and being held in "several small steps”, which aligns with the distribution illustrated above by Cross. Given these factors, it is interesting to note here an approximation of design activity with the intended work progress on Scrum projects through the "consumption" of product backlogs item, which is even more apparent by visualizing a burndown chart commonly used by practitioners the framework (SUTHERLAND, 2005). All of these possible alignments suggest the appropriateness of choosing Scrum as setting agile context for our work, which we will further detail in the next chapter.

## 2.3 DESIGN AS AN INTEGRATIVE TOOL FOR BALANCING ORGANIZATIONAL MANAGEMENT

The first contributions for Design Management are attributed to Peter Behrens’ activities within AEG and Olivetti’s corporate design in the beginning of the 20th century, but

Design Management as a field of study started growing in the 1960s due to the need of analyzing the implications of inserting the then newborn design methodologies in the organizational context (BÜRDEK, 2005). In the 1980s, this field receives an extra attention with the perception that design could, besides aesthetical benefits, lead to economic gains (BÜRDEK, 2005).

In terms of emphasis, our research is in line with the "design project management", which is one of Design Management's front, that establishes the place of design in project-oriented organizations, recognizing its role as a link between creativity and innovation to business' operational control tasks (GORB, 1986). In a more general sense, our discussion is mostly centered on how design's activity in projects can serve as a balancing and integrating factor between organizational needs and its context.

Nowadays, Design does not focus only on discussions about their products, but on a much larger scope. As a strategic tool, it should primarily address needs in two vectors: users and organizations (BAXTER, M., 2000; CROSS, 2000). Often these dimensions may present themselves in a conflicting manner, for example, a demand for a particular functionality can increase product's costs for the developing organization. Whilst these groups of need may be conflicting, they have a direct influence on one another (LÖBACH, 2001). The appropriate balance between them is essential to the success of any initiative of the designer, especially in the eyes of the various involved stakeholders.

On users needs, Löbach elaborates the following perspective (LÖBACH, 2001): "[...] many of human needs are satisfied by the usage of objects. This happens through product functions that, in the usage process, manifest as use values." This is why this author denoted a triad of functions that each product must contemplate to satisfy user needs, namely:

a) Practical function: function that addresses physiological needs during product usage.

b) Aesthetical function: corresponds to the relation that an individual has with a certain product through its sensorial capabilities.

c) Symbolical function: this function links up meanings and experiences (spiritual, psychological and social) already lived by the user.

A designer will rarely handle a given problem without any organizational constraint as well, so she should be concerned with an assessment against contextual criteria of the problem on the table, such as cost (CROSS, 2000). But design process should not be based only on production cost, if that occurs, it might happen at the expense of leaving out other equally important criteria – either technical and economic – that often cannot be measured financially (PAHL; BEITZ, 2013). Therefore, the designer must also take into account a wide range of organizations' needs prior to a given problem (such as revenue, return over investment, corporate image, etc.).

In our case, we chose three dimensions to be considered while handling Little Design Up-Front phenomena: product, business and process, which will be further detailed in the following subsections.

## 2.4 THEORETICAL FRAMEWORK

To properly discuss design activity, we will detail some complementary perspectives, which will set a theoretical basis for what will revert in a context for practical applications. The three dimensions presented here helps to understand and frame a specific approach in handling our research problem.

### *2.4.1 Design Thinking for product dimension*

In our research, the dimension of product concept will be addressed by Design Thinking, which solely represents a relevant scientific advance for design in terms of a new perspective for this discipline inside agile projects´ environment. Because, as already mentioned, previous work dealing with this context focus mainly in areas related to user interfaces production - for example, Interaction Design or Usability (BRHEL *et al.*, 2015; SILVA, T. *et al.*, 2011; SOHAIB; KHAN, 2010). Besides that, Design Thinking can also embed effectiveness to the product to be developed, since this area is focused on problem solving centered at the user.

It is a useless effort to try to define Design Thinking through a single perspective (KIMBELL, 2011). The way "design thinks" can be divided into two major discourses: Designerly Thinking and Design Thinking (JOHANSSON-SKÖLDBERG; WOODILLA; ÇETINKAYA, 2013) (a similar position is presented by Kimbell (KIMBELL, 2011)). The first being a purer academic form, and focused on the design itself, while the second is an extension or appropriation of design thought for the segment of organizational management. For the sake of simplicity, we will just use the term Design Thinking, despite our effort indeed points towards both perspectives, according to Johansson-Sköldberg and colleagues' classification.

Our guidance for products conception is close to what Dorst called "Abduction-2", which is suitable when the designer still has no clear notion of the "what" (object) or the "how" (working principle) to deliver value to the user (DORST, 2011). The author mentions that it is a more complex way, but closer to the practice of design thinking, where the designer creates new "frames" for treating a particular problem (new working principles lead to new values for users). The configuration of these new frames should be guided by a certain number of criteria for the design product, which are usually defined by government regulations, industry standards or the customer / consumer (CROSS, 2000).

Regarding the location of the Design Thinking activities during new product development process, our research will use the approach classified as “front-end” (LINDBERG; MEINEL; WAGNER, 2011). It places Design Thinking in the beginning of the project, before any other activity, as software coding for example. According to Lindberg, this approach allows an easier integration of Design Thinking practice in software development environment, since the conflicts among domains are minimized. Also, a certain amount of design being done at outset has a positive impact on user satisfaction, mitigates risks and helps keep the budget and the schedule (FERREIRA; NOBLE; BIDDLE, 2007b). These authors’ argument relates to Interaction Design practices, whereas ours will observe the same phenomena through Design Thinking practices, representing a newer perspective for Design, as a discipline.

### 2.4.2 Lean Thinking for process dimension

Lean Thinking can be understood as a set of practices that analyzes organization’s value chain and aims to maintain only what quickly creates value for the customer (POPPENDIECK, M., 2011). This may be of interest considering Little Design Up-front’s need to generate the smallest possible amount of waste during a project. Lean paradigm with respect to process modeling is based on systems thinking: structure guides behavior (LEON; FARRIS, 2011), so the Lean Thinking’s perspective might be relevant to observe the dimension of design process in our work.

Poppendieck listed four principles of Lean development and, due to its historical connection with manufacturing, transposed them to software development. Among four principles listed by the author, we selected three most related to product process itself (POPPENDIECK, M., 2011):

- Add nothing, but value (eliminate waste): develop only the most important features and detail only requirements to be worked out in the current cycle.
- Flow value from demand: deliver only what is perceived as value and pulled by demand.
- Optimize across the organizations: transactions and integration between departments should be less costly as possible.

Complementarily, Reinersten listed the twenty-two principles focused specifically on reducing the size of (job) batches, which may be understood in the context of our research as an attempt to address Little Design Up-Front. We selected four principles more focused on processes related to product development (REINERTSEN, 2009):

- Reduce product cycle time: get feedback more quickly and possibly increase earnings per cycle.
- Loose coupling of subsystems: the architecture should maximize the full inclusion of new components with low impact.
- Sequence first that which adds value most cheaply: reduce the financial exposure to cumulative risk, this ideally creates a convexity between the curves of benefits and costs accumulated over time.
- Adjust batch size to respond to economic changes: aspects that lead to the optimal batch size change over time, especially costs.

Lean Thinking evolved sufficiently to be applied across organizations and industries not directly related to manufacturing (STONE, 2012), moreover there is already a large number of mature enough tools associated with this paradigm that might be used when mapping value throughout the product processes of organizations (HINES *et al.*, 1998; HINES; RICH, 1997).

More recently, these Lean principles have been translated into a strategic entrepreneurship framework called Lean Startup by Eric Ries (RIES, 2011). This framework values “experimentation over elaborate planning, customer feedback over intuition, and iterative design over traditional ‘big design up front’ development”, according to Blank (BLANK, 2013). In order to optimize any organizational activity through this model, the whole concept of new product development, which includes design activity, must happen with less effort as possible and be iteratively validated through real-world market interaction with users and costumers early-on in the process.

Ries (RIES, 2011) came up with a concept that materializes this perspective called Minimum Viable Product (MVP). According to him, a MVP is “[…] that version of the product that enables a full turn of the Build-Measure-Learn loop with a minimum amount of effort and the least amount of development time […]” and “[…] is designed not just to answer product design or technical questions. Its goal is to test fundamental business hypotheses.” This type of approach is especially designed and important for companies that lack resources or operates in highly innovative contexts, such as software start-ups. Thus, it is indeed important to see the implications for design activity when bringing Lean and Design Thinking perspectives to the same context, as these two line of thoughts have similarities and differences among them, as shown below (MÜLLER; THORING, 2012):

Table 5 – Comparison between Design Thinking and Lean Startup models

| What | Design thinking | Lean Startup |
|---|---|---|
| Goal | Innovations | Innovations |
| Scope, Focus | General innovations | High-tech innovations for Startups |
| Approach | User-centered | Customer-oriented |
| Uncertainty | Solve wicked problems | Unclear customer problem |
| Testing | Fail early to succeed sooner | Pivoting is at the heart of the 'fail fast' concept. The sooner you realize a hypothesis is wrong, the faster you can update it and retest it. |
| Iteration | Yes ("Iteration") | Yes ("Pivoting") |
| Ideation | Ideation is part of the process, solutions are generated in the process | Ideation is not part of the process, product vision is initially provided by company founders |
| Qualitative Methods | Strong focus: elaborated ethnographic methods, user research, observations, etc. | Not a focus |
| Quantitative Methods | Not a focus | Strong focus: metric-based analysis; provides matrices, and testing |
| Business Model | Not a focus | Focus |
| Adaption of deployments | Not a focus | Five Whys Method |
| Typical Methods | Shadowing, Qualitative Interview, Paper Prototyping, Brainstorming (with specific rules), Synthesis, etc. | Qualitative Interview, Smoke Test, Paper Prototyping, Innovative Accounting, Split (A/B) Tests, Cohort Analysis, Funnel Metrics, Business Model Canvas, Five Whys, etc. |
| Hypothesis Testing | Not a focus | Focus |
| Prototype Testing | Yes | Yes |
| Rapid iteration | Yes | Yes |
| Target Group | Users (usually end users, sometimes other stakeholders) | Customers (distinguished between Users, Influencers, Recommenders, Economic Buyers, Decision Makers) |

Source: (MÜLLER; THORING, 2012)

In our work, the context is set by Design Thinking being applied to conceive digital artifacts under agile paradigm, so it may be the case that, regarding Little Design Up-Front, conceiving a MVP might prove useful to this purpose. The idea of having a validated vision for a specific product early on amplifies the effectiveness of LDUF. "A possible misinterpretation regarding the suitability of a technical solution in the early concept phase can ultimately lead to late changes and iterations", according to Schuh et. al (SCHUH; LENDERS; HIEBER, 2008). Lean startup acts upon several uncertainties in order to constantly direct a specific solution towards validated costumers´ need (RASMUSSEN; TANEV, 2015). Thus, suitability, as the alignment of a specific solution considering the overall strategy of an organization and real-world problems (e.g. user needs), is an important criterion that will considered further in our research.

### 2.4.3 *Incremental Innovation for business dimension*

Before delving into the specificities of innovation it is important to take a step back and define it in terms of creativity, as both concepts are central criteria in the experimental part of our work. When talking about them, our research will adopt the definition by Amabile (AMABILE, 1988) that states creativity as "[…] production of novel and useful ideas by an individual or a small group of individuals working together". She also continues in defining innovation as a function of creativity: "Organizational innovation is the successful implementation of creative ideas within an organization." It is important to notice the subtleties in the relationship of both, while creativity is a trait of groups in producing a specific type of result, innovation can only be considered when taking account organizational needs, meaning it only happens considering the constraints of a market.

Classically, design expects to generate all or most of the specifications prior to the development of the product itself (CROSS, 2000). However, nowadays the discipline must be constantly integrating business innovation needs, especially in an incremental scenario as the one set by agile for digital products. Incremental innovation can serve design with specific directions regarding the need for business viability of a product. Viability, as discussed here, is the result of market attractiveness or success for a product and this is one of the most important dimensions for Design Thinking (BROWN, T., 2009).

Incremental innovation can be defined as being (NORMAN; VERGANTI, 2014): "[…] performed as a result of a deliberate design research strategy or through a series of mutual adaptations by the product developers and the use community to bring the two into better alignment". Regarding the extremes of radical and incremental innovation, instead of opposing, these authors state that they are in fact complementary, since the first sets new possible limits for a product, while the latter allows better capture the full potential of this radical change. This statement is endorsed by Varadarajan who goes on to list a number of important roles of incremental innovation in the competitive strategy of companies, such as: entrance into new markets or adapt to industry ecosystem (VARADARAJAN, 2009).

Some studies weigh heavily the factor of pioneerism for success in a particular market, while others point success as strongly associated also with other factors such as lower risk and lower cost of development, which can be obtained by "followers" more associated with the practice of incremental innovation (BROWN, K.; SCHMIED; TARONDEAU, 2002). During the practice of concurrent engineering – overlapping stages and functions in the development of new products (similar to agile context) –, incremental innovation is positively associated with superiority on the developed product and reduction of development time (VALLE; VÁZQUEZ-BUSTELO, 2009). There is a number of factors that favors the practice of incremental innovation, such as: environmental dynamism and structural linkages within an organization (exchange of information between functional sectors) (KOBERG; DETIENNE; HEPPARD, 2003).

Incremental innovation can be classified into three types: continuous, modified or process (KOBERG; DETIENNE; HEPPARD, 2003). "Continuous" corresponds to the extension of existing products, "modified" deals with the introduction of newer technology and "process" which relates to the improvement in the production of a certain product. As can be seen, incremental innovation has a set of characteristics that can be supportive for design as being able to deliver the expected business value to its customers in the context of an agile project when dealing with Little Design Up-Front.

### *2.4.4 Discussion*

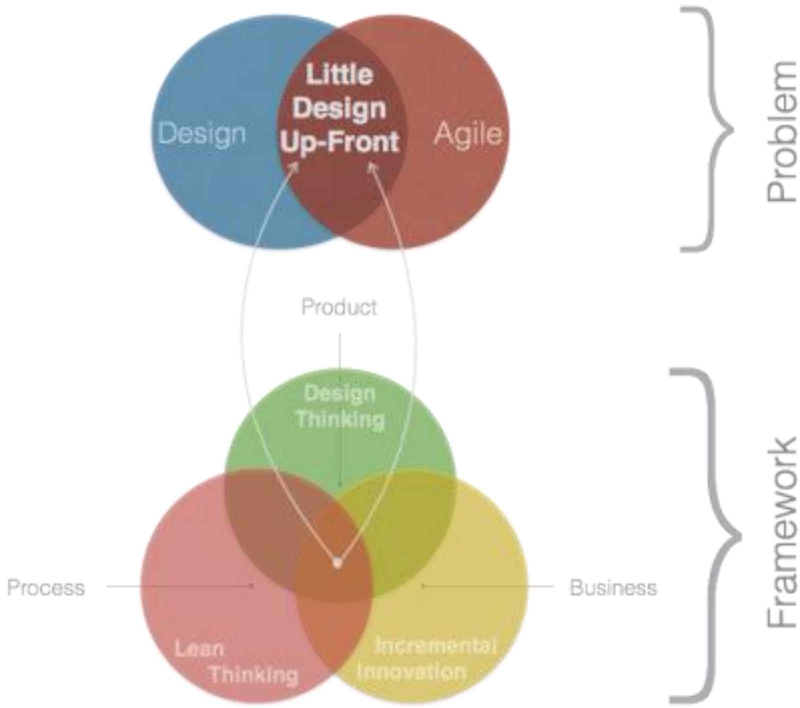
Tim Brown defines Design Thinking as (BROWN, T., 2008):

> “A discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity”.

From his definition, we can restate Design’s concern regarding its role as an integrative discipline, which is crucial for our theoretical framework as a whole.

As for agile methodology to set project context, we will center our discussion on Scrum (SCHWABER, 2004), because it is a management framework that is less focused on software practices (KNIBERG; SKARIN, 2010) and introduces new theoretical implications which are not observed in traditional project management methodologies (KOSKELA, L.; HOWELL, G., 2002a, 2002b). Like Scrum, Design Thinking is an action-based practice (Scrum delivers incremental “working software” and Design Thinking, “prototypes”) and fosters collaboration (FRYE; INGE, 2013). Despite these similarities, there are some points of discrepancy, especially with regard to the perception of waste generation (FRYE; INGE, 2013). A crucial point is the transfer of design knowledge at the interface with later development stages, for which is still needed a modus operandi (LINDBERG; MEINEL; WAGNER, 2011). It is in this context that the problem of the Little Design Up-Front is brought up, which we will analyze and intend to address by multiple perspectives, as depicted in Figure 8.

Figure 8 - Theoretical framework for addressing research problem context




Source: created by the author

Despite the fact that Design Thinking might introduce some results that can be perceived as “waste” by Lean, it is understood as essential to deliver higher quality results and minimize rework in the long run (FRYE; INGE, 2013). Therefore, it is necessary a proper balance between market-pull models (market demand) and technology-push (creating new demands) (CROSS, 2000). This conflict is especially evident if we consider the principle of "abduction-2" as being closely related to Design Thinking (DORST, 2011), which means that sometimes designers does not have a preview and full view of the product to be developed. This can potentially collide (and be complemented) by Lean’s principles for process efficiency. Efficiency, when considered on cross-organizational interactions, is essential to create a proper environment for innovation – either radical or incremental (KOBERG; DETIENNE; HEPPARD, 2003). Hence the importance of the principles of Lean paradigm for Design Thinking in order to promote interdisciplinary integration in the context of Little Design Up-Front on an agile project, a situation where designers must interact with various stakeholders and constantly deliver intermediary results in many short, iterative cycles. Likewise, design as a discipline has a more complex definition of value, a central concept for both Lean Thinking and Agile paradigm, which can complement a more limited or unstructured view from these management perspectives.

Incremental innovation should be understood as the result of team effort and not only individual (KOBERG; DETIENNE; HEPPARD, 2003), which aligns with the multidisciplinary collaboration approach promoted by Design Thinking. Following Koberg´s classification for incremental innovation types, it is expected that agile project context itself strongly stimulates continuous incremental innovations (product improvement) (KOBERG; DETIENNE; HEPPARD, 2003), as, for example, Scrum delivers “product increments” in each cycle (SCHWABER, 2004). So it may be essential the role of Design Thinking in promoting "modified" incremental innovation for insertion of new technological capabilities (or creation of “new frames” in problem solving, according to (DORST, 2011)). This balance introduced by Design Thinking can prove valuable, since agile projects tends to prioritize mostly incremental progress, which may limit divergent thinking (LINDBERG; MEINEL; WAGNER, 2011).

Most organizations change in an evolutionary manner, that is, adjusting or enhancing part of its activity across time (STONE, 2012). Back to the classification proposed by Koberg, another type of incremental innovation is the "process" improvement one (KOBERG; DETIENNE; HEPPARD, 2003). This type of innovation can be easily related to the principles of Lean Thinking, as pointed out by Chen and Taylor (CHEN; TAYLOR, R., 2009): “[…] the continuous improvement initiative in lean is likely to have a positive impact on incremental process innovations”. However, these authors also point out that Lean’s excessive need for compliance can limit innovation capacity as a whole, so they advocate a better balance between creativity (innovation) and structure (lean) to extract the best of both worlds.

It is through this disciplinary triad (Design Thinking, Incremental Innovation and Lean Thinking) that will be discussed the occurrence of Little Design Up-Front. The interplay between agile context and this triad is stated by Conforto et. al (CONFORTO *et al.*, 2016) as indeed needing further investigation to evaluate their impact on team’s performance, which further substantiates and justifies the choice of such theoretical dimensions for our study. This theoretical triad also enabled our research to define the criteria (creativity, innovation, suitability and viability, as previously presented in this chapter), which will be considered in the experimental part of our work.

# 3 DESIGN THINKING CANVAS AUTONOMUS

In this chapter, we set out to detail the operational aspects of Design Thinking Canvas, which stands as our source in terms of design methodology to be explored. Following, we present the proposed automation for this methodology called Design Thinking Canvas Autonomus by introducing its ontology and later its internal functioning as a software app to support and automate design process.

It is important to make clear that even though we describe a technological tool in this chapter, our main objective, in terms of scientific contribution to Design field, is to make use and evaluate Autonomus' capabilities to check the level of its support for agile's Little Design Up-Front issue and possible implications for designers' activity.

## 3.1 RELATED WORKS ON SUPPORTING DESIGN PROCESS THROUGH TECHNOLOGY

As we did with agile project context in the previous chapter, it is also important to review the state of technological support for design activity and the implications that comes from that. This section also discusses aspects of technological automation and knowledge management for design practice as it is normally associated to a human-only activity. It is a central aspect in terms of how we target Little Design Up-Front phenomena in our research.

There is no need to restate the importance of computational tools for contemporary work environment, but computational thinking has been reported as being strongly correlated to problem-solving ability (ROMÁN-GONZÁLEZ; PÉREZ-GONZÁLEZ; JIMÉNEZ-FERNÁNDEZ, 2017). This is especially important considering that amongst the most relevant digital skills for the 21st century are: creativity, critical thinking and problem solving (LAAR, VAN *et al.*, 2017). This represents the capacity to employ technological tools to come up with new ideas, make better reasoning with data and provide solutions, respectively.

When designing automated systems, "[…] the design challenge shifted from using the technology to shape behavior (ensuring procedural compliance) to using it to shape cognition (increasing perspicacity and insight)", according to a commentary by John Flach on (NORMAN; STAPPERS, 2016). Automated systems' accuracy has serious effects on its reliability, as even future improvements leads to lower gains on this aspects (MADHAVAN; PHILLIPS, 2010). For instance, chatterbots are tools that employs artificial intelligence techniques in order to establish natural communication with human beings. They been recently applied to work on unstructured environments like social media, for example. In a study focused on Twitter social network it was found that, regarding communication with a chatterbot, people had equivalent levels of learning capabilities when compared to a human agent (EDWARDS, C. *et al.*, 2016). In the hardware domain, some research has been conducted to model the interaction between human operators and automated robots (YAGODA; COOVERT, 2012). Considering human-agent teamwork, the fact of being led by an agent was not a factor of team abandonment by humans (WISSEN, VAN *et al.*, 2012). Transposing to our research context, this clearly indicates possibilities of using this type of tools to aid design process in collaboration between humans and computational agents.

For design process, it is important to note that introducing computational tools to aid or support it should not happen without acknowledging and controlling unwanted effects already identified, namely: circumscribed thinking, premature fixation and bounded ideation (ROBERTSON; RADCLIFFE, 2009)(BERNAL; HAYMAKER; EASTMAN, 2015). Liddament (LIDDAMENT, 1999) states that computational tools usually materializes an “ontological reduction” in the sense that in only approximates reality, while design is most of the time dealing with real-world entities or objects. A natural conflict comes from that.

Designers’ tacit knowledge, as unstructured as it is, has found very weak support in terms of computational tools and they have mostly been “design-centric” instead of “designer-centric”, in the sense that supporting product development usually overrides designer (as a user) needs (BERNAL; HAYMAKER; EASTMAN, 2015). These researchers have also shown that agent-based computations (our research focus) have not yet addressed important designer’s actions such as: forming analogies, co-evolving problem and solution, recalling conceptual structures and recalling recognizable problems.

Baxter and colleagues (BAXTER, D. *et al.*, 2008) argue that knowledge management through technology tooling should indeed expand itself towards design activity, as it can potentially free up companies’ resources in the search for innovation in competitive markets. They identified five types of approaches for classifying design knowledge management: computer-aided design (CAD) models retrieval, methodology, function, ontology and process. Likewise, Kitamura and Mizoguchi (KITAMURA; MIZOGUCHI, 2003) proposed a framework for device ontology as a way of achieving interoperable and consistent models among designs. They have applied it for functional decomposition of devices in very specific domains (e.g. fluid-related plants), and acknowledge that others are still to be developed. Also referring to engineering design, an interesting finding from Ahmed (AHMED, 2005) was that the experience of a designer affects how they express themselves about their activity and consequently the formulation of an ontology.

Considering the whole spectrum of design process, it is interesting to be able to convert functional mappings in configuration representations (KURTOGLU; CAMPBELL, M. I.; LINSEY, 2009). These researches did so through a software program that receives a functional model as input, processes possible combinations and generates configuration-based outputs, but still as a model. Nevertheless, their analysis showed that these configuration models helped designers during concept generation considering the metrics of: completeness, novelty and variety. These findings counterpose some of the worries reported in the beginning of this section.

After reviewing these works, we can see that, albeit having already achieved relevant results, automating or supporting designers' activity through computational tools still have plenty room for contribution. We can also note that most of the studies focuses within engineering design and deals with functional representation of products. Alternatively, our approach is based on a specific design methodology which we will explicit its main concepts in computational structures, so they can be represented and processed through artificial intelligence. Our objective is to aid designer's conceptual activities, sticking to the "attitude of enabling and emergence" (PESCHL; FUNDNEIDER, 2014) as so much needed by agile projects.

## 3.2 DESIGN THINKING CANVAS METHODOLOGY

Design Thinking Canvas (DTC) (CALADO *et al.*, 2016) is our main focus in terms of design framework. It materializes all computational concepts discussed later in this chapter, so we will detail the description of the methodology before entering on its computational implementation.

Design Thinking Canvas is a multidisciplinary design thinking methodology that was created and has been maintained by GDRLab research group at Universidade Federal de Pernambuco. Inspired by Business Model Canvas (OSTERWALDER; PIGNEUR, 2010) and Lean Canvas (MAURYA, 2012), DTC also employs a canvas as a basic structure to register all of its information (see figure 9). The difference from these canvases tooling is that DTC, as a design methodology, besides the "what" it also defines "how" designers should develop such information by applying its prescribed methods (ARAÚJO, A., 2013). DTC's suitability to agile projects can be stated due to the fact that it compiles to a certain level the most used techniques regarding agile requirements, namely: Human-centered design, Design Thinking, Contextual Inquiry and Participatory Design (SCHÖN; THOMASCHEWSKI; ESCALONA, 2017).

Several scientific works have been developed using Design Thinking Canvas as their main foundation, which helped to develop the methodology itself across time and domains, for example: sustainability (SÓTER; VILAR, 2016), game development (CREDIDIO, 2007; FILHO, 2014; OLIVEIRA, 2015; TEOFILO ALVES, 2011) and business models (VARGAS, 2015). Besides this academic context, DTC has also been applied within several Brazilian companies aiming the creation of innovative products for the last 10 years. Therefore, it was possible to historically collect and index several validated data points, which reflects design knowledge around: desirability (user profile and needs), feasibility (technological capabilities) and viability (business strategy), being these central dimensions for Design Thinking (BROWN, T., 2009).

Design Thinking Canvas functioning is comprised of four sequential phases: [1] Observation; [2] Conception; [3] Configuration and [4] Publication (see Figure 10). During its execution, designers are able to rigorously develop the information for each of the fifteen blocks in the canvas as they have design methods associated to them.

It starts with **Observation**, during which the methods applied to complete its blocks are: direct and indirect observation (BERG, 2001), persona (HANINGTON; MARTIN, B., 2012), benchmark (JENNINGS; WESTFALL, 1992) and desk research (CROUCH; HOUSDEN, 2003). *Scenario* block stands for a description of environment where the problem observed takes place, it might be a physical, virtual or conceptual space. The *persona* block aggregates all of the agents' profiles to be considered in addressing the problem as they might convert into users or costumers of the solution to be developed. It materializes raw data in a more personal relatable perspective as fictitious characters are created. *Opportunities* summarizes the open gaps that can possibly be explored by the solution yet to be developed. They are inferred from the problems identified from personas' context. As a way to benchmark and differentiate itself, the *Competitors* block lists all of the existing solutions that compete direct or indirectly in the same market.

**Conception** phase is the stage mostly associated with creative work in the methodology, it applies specific adaptions of the following methods: Value Proposition (OSTERWALDER *et al.*, 2014), Brain Writing (VANGUNDY, 1984), Heuristics (BREYER, 2008), Value Curve (KIM, W. C.; MAUBORGNE, 2004) and Storyboard (HANINGTON; MARTIN, B., 2012). In *differential* block, it is supposed that design team make explicit what makes the solution unique in terms of technology, domain or market aspects. A natural derivation from this block is *value proposition* one, where the team states what values does this solution adds to its users' life visualizing it through a comparative curve. The *ideas* block comes from all the concepts generated from the divergence that is collaboratively developed by all team member through Brain Writing method, the objective is to achieve diversity by a large number of ideas. From this previous block, *solution* stands to the selection of the best concepts in a collaborative way through the application of specific heuristics as the best ideas are evaluated on desirability, feasibility and viability dimensions. As we have a group of concepts to me merged, the design team can develop a storyboard that maps out the *experience* as a user journey.

Next, there is the **Configuration** phase where the solution is materialized. As DTC is normally associated with technological artifacts, so in this phase we have the development of user interface layouts (*form* block) and main functionalities specification/requirements (*function* block).

Finally, during **Publication,** DTC's team define the strategy for the product in three main dimensions: user acquisition, retention and monetization, which stands as an adaptation from Pirate Metrics framework (MCCLURE, 2007). *Acquisition* refers to the tactics applied to attract new users to the product, while *retention* aggregates the ones responsible for retaining the existing users in order to maintain high levels of active usage. *Monetization* by its turn refers to the channels to be explored in order to generate financial gains from users' activity. Lastly, the *validation* block reflects a set of six heuristics to test user acceptance for the proposed solution.

Figure 9 - Canvas blocks from DTC


Source: (NEVES, 2014)

Figure 10 - Design Thinking Canvas phases: Observation, Conception, Configuration and Publication


Source: (NEVES, 2014)

## 3.3 AN AUTOMATION FOR DESIGN THINKING CANVAS

As previously stated, our research is centered on conceptual design, which is defined by Pahl and Beitz (PAHL; BEITZ, 2013) as being:

> "[…] part of the design process in which, by the identification of the essential problems through abstraction, by the establishment of function structures and by the search for appropriate solution principles and their combination, the basic solution path is laid down through the elaboration of a solution concept".

Accordingly, in this section, we present the proposed automation tool for Design Thinking Canvas methodology, called "Design Thinking Canvas Autonomus". First, we introduce its ontology which represent its computational structure to make all of its data processable and later all of Autonomus' internal functioning to support design activity is further detailed.

### *3.3.1 An ontology for conceptual design automation*

New design methods have two features, according to Cross (CROSS, 2000): [1] they externalize design thinking and [2] formalize certain design procedures, in order to avoid the oversight of important factors. Thus, as a direct derivation from the previously presented DTC's framework (NEVES, 2014), Autonomus' methodological concepts needs to be formalized through a computational structure called ontology. Ontologies are "a formal, explicit specification of a shared conceptualization" (FENSEL *et al.*, 2001; GRUBER, 1993). This kind of structure might prove useful in order to map design's process for a specific domain. We did so by developing an initial ontology focused on digital apps' creation domain, so that this process can also be viewed as part of a knowledge management across time (FENSEL *et al.*, 2001). Ontologies can be created through three approaches: bottom-up, top-down and middle out (CRISTANI; CUEL, 2005a). This way, these authors state that this database can be maintained and possibly generate automatic artifacts, which can, to a certain extent, aid design activity in the process of "product discovery" or "product research" for Little Design Up-Front (BRHEL *et al.*, 2015; SILVA, T. *et al.*, 2011), as intended in our research.

Design Thinking Canvas Autonomus' ontology is focused on software apps. Our motivation comes from the fact that this segment has been a huge and extremely competitive market specially since the advent of massive platforms for digital content distribution, like: Apple's App Store or Facebook.

Creating an ontology is a way of making knowledge explicit and serves as a crucial step to make it machine readable (CRISTANI; CUEL, 2005b). The data was structured in an xml format named as DTML (Design Thinking Markup Language). This is a widely used format within computational tools and allows a flexible modifications in the future ("XML", 2016). They have information about user needs, technology capabilities and business strategies extracted from real market data, as previously said. The DTML is composed by four XML files: [1] *personas.xml*; [2] *activities.xml*; [3] *features.xml*; and, [4] *arm.xml*.

The *personas.xml* file has customer's profiles. In each profile, there is a fictional representation with information like: name, region, social class, age, an image to represent the persona and some description of it. It reflects the results of previous application of

Personas method (HANINGTON; MARTIN, B., 2012) using DTC's methodology. Our database is initially comprised ten personas (see Table 6 for an example).

Table 6 – Persona entry example

```
<persona>
    <name>James</name>
    <region>North America</region>
    <social class>Middle class</social class>
    <age>Thirties</age>
    <big area>BUSINESS</big area>
    <image>persona_james.png</image>
    <description>James is look for a new job after working for 3 years in the Underwriting department of Acme Insurance. At 34 years old, James is extremely active. He surfs twice a week in the summer and swims lapse three times a week in the winter. He actively uses apps for business productivity, discovering job opportunities and business training. He usually makes fitness at his freetime.</description>
</persona>
```

Source: Autonomus source code

The activities.xml has information about daily activities from personas' life. In each activity, the DTML provides a title, an area, a description and a list of personas that are related to it. Our initial database has thirty four activities (see Table 7 for an example).

Table 7 – Activity entry example

```
<activities>
    <activity>
        <title>medicine</title>
        <big area>HEALTH</big area>
        <description>take medicine with controlled time many times a day</description>
        <persona>James</persona>
        <persona>Mary</persona>
        <persona>Robert</persona>
    </activity>
</activities>
```

Source: Autonomus source code

The *features.xml* has a list of app features. For each activity, we have about ten features in this file. In each feature, we have: an app reference (the app that originally has it), the description of the feature, the associated activity and three tags, keep, raise and create. This tag categorization of each feature is done through the concept Value Innovation through the Four Actions framework (KIM, W. C.; MAUBORGNE, 2004), regarding if the feature can keep, raise or create factors for value in this activity. Our database has three hundred and eighty six features. It results from previous iterations of Design Thinking Canvas using previously presented methods of: desk research, observation and benchmark from success cases within apps domain. Table 8 shows an example.

Table 8 – Feature entry example

```
<feature>
        <reference>Snapseed</reference>
        <description>users can crop their scenes</description>
        <activity>photography</activity>
        <keep>yes</keep>
        <raise>yes</raise>
        <create>no</create>
</feature>
```

Source: Autonomus source code

The *arm.xml* file has three lists of business strategies. One list with user's acquisition strategies, another with user's retention strategies and other with monetization strategies. It uses the same structure and rationale described on DTC's Publication phase for these dimensions. Our initial database has sixty four business strategies (see Table 9 for an example).

As a well-structured design methodology and, consequently, conceptual definition already existed, this ontology was constructed through a 'bottom-up approach'. It is a way of doing so by starting from existing concepts and later classifying (or generalizing) them (CRISTANI; CUEL, 2005b). Regarding our main objective of conceptual design support and automation, this is a specially important step to create a set of computationally processable data for future usage in design context.

Table 9 – ARM entry example

```
<arm>
    <acquisition>
        <strategy>Offers by email</strategy>
        <description>Ads based on mailing lists</description>
    </acquisition>
    <retention>
        <strategy>notifications</strategy>
        <description>Use push notifications</description>
    </retention>
    <monetization>
        <strategy>Sponsored content</strategy>
        <description>Content sponsored by brands, including in-app virtual goods, or “limited-time only” features</description>
    </monetization>
</arm>
```

Source: Autonomus source code

### *3.3.2 Design Thinking Canvas Autonomus description*

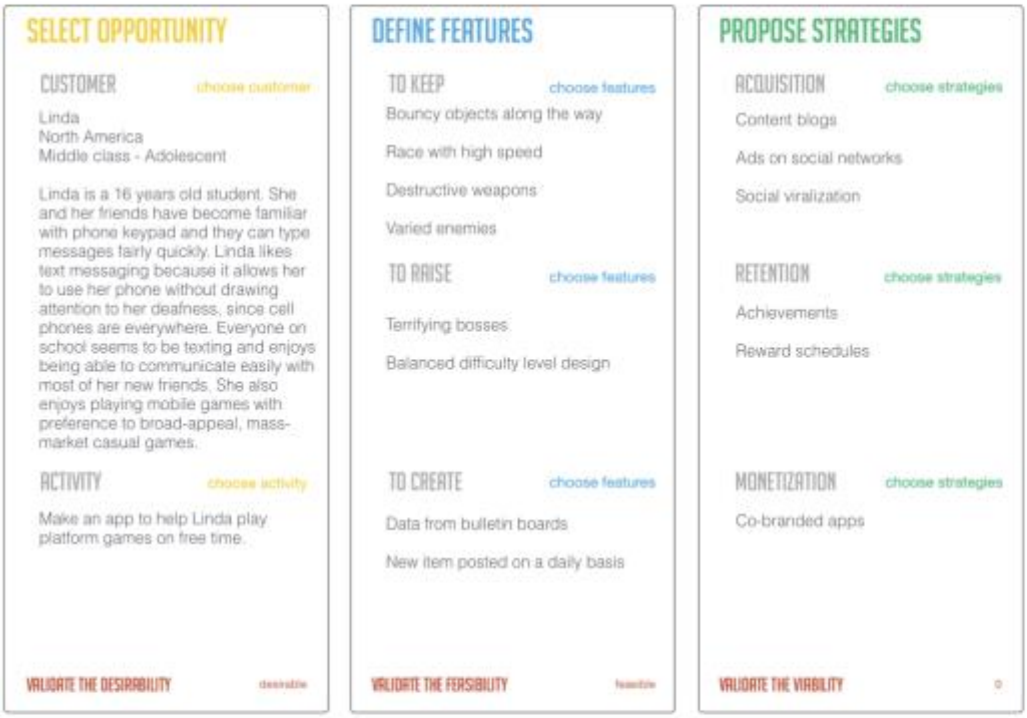
The integration of design activities within agile projects sometimes tends to be perceived as being more research-oriented than properly helping to deliver working software (LARUSDOTTIR; GULLIKSEN; CAJANDER, 2017). In order to address this issue, for the long term, we propose an abstract computational machine which employs two groups of intelligent agents: [1] first group with skills to search the Internet (or other database) and build a structured database related to our methodology and domain; and, [2] a second group of agents that make decisions and propose innovative artifacts. In this work, we are focused only in the second group agent which is developed as an iOS app. This app is called Design Thinking Canvas Autonomus in order to reflect the inspirational design methodology and its new purpose at the same time.

Using the structure described in the previous section, Design Thinking Canvas Autonomus can combine several of these data in order to conceive mobile apps within its correspondent design methodology framework. It is intended that most of the app users will be designers interested in a support for conceptual stages of their projects.

The main blocks shown in the canvas are related to the *opportunity* to be explored, *features* to be developed and *strategies* to be adopted. All of the basic information for each of these canvas blocks can be automatically generated by the app (as seen in Figure 11). This can be done by clicking in each of the blocks title. Alternatively, the designer can go step by step deciding which information to pick (see Figure 12), this can be done for all of the blocks and respective sub-blocks. Later, the designer can evaluate through heuristics if these suggestions are adequate for the problem to be addressed or not before moving to the subsequent block (see Figure 13).

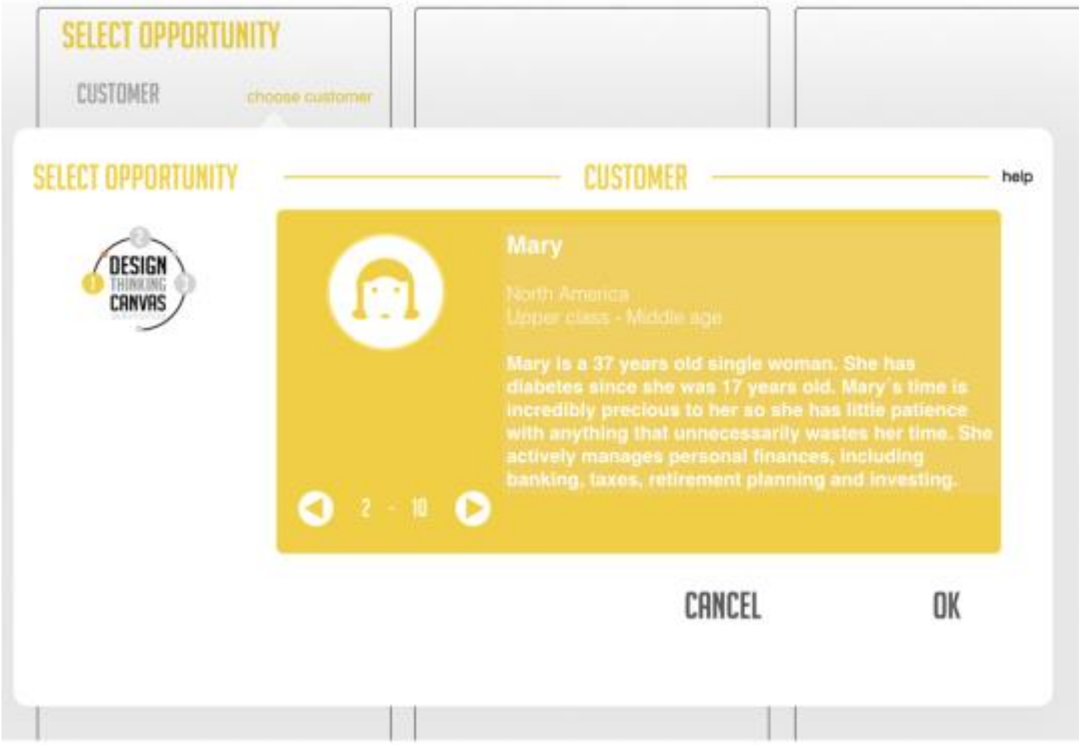
The idea of addressing Little Design Up-Front with the support of Design Thinking Canvas Autonomus is to enable what Norman and Stappers (NORMAN; STAPPERS, 2016) call "incrementalism" as: "[…] the process of moving forward in small, considered steps, fitting the opportunities offered by each successive present, rather than by tackling the entire problem all at once with a single leap into an unknown future". Also, it is important to note that building a shared understanding of user requirements knowledge is identified as one of the most important aspects to agile projects (SCHÖN; THOMASCHEWSKI; ESCALONA, 2017). Although it does not provide detailed information, this type of visual representation in Autonomus' canvas is particularly important for agile projects. Visual management tools are reported to improve teams' agility performance when combined with other techniques in this type of project (CONFORTO *et al.*, 2016). This way, in their pursuit of Little Design Up-Front, agile projects can set a common vision for all of its teams regarding what the product to be developed must achieve. At the same time, design details or refinements can be done in emergent way across time, as the design team becomes more aware of the problem to be solved or come across further opportunities and feedbacks.

Figure 11 - Overview of an automated suggestion by the app



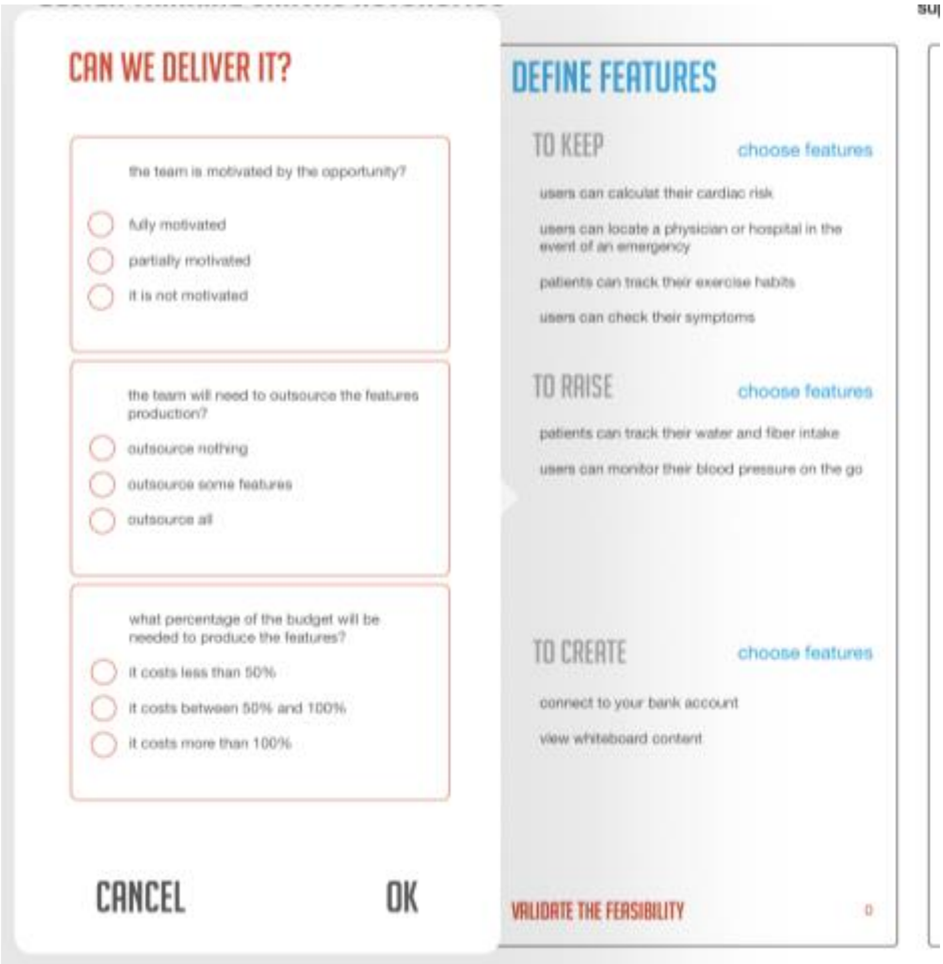

Source: Screenshot from Autonomus app

Figure 12 – Screenshot: choosing a persona from Autonomus' database




Source: Screenshot from Autonomus app

Figure 13 - Screenshot: Heuristics evaluation of the features to be included




Source: Screenshot from Autonomus app

# 4 RESEARCH METHODOLOGY

Our overall research problem stands as a way to evaluate to which level computational support can help design activity to address Little Design Up-Front within agile projects. To do so, we divided our experiment in two complementary studies: [1] the first one intends to investigate the efficacy of the technological tool to generate design concepts by itself in comparison to how a human designer would perform; and [2] a second study that will reflect evaluations of real-world agile projects, considering also the development of products, while applying different levels of technological support for Design Thinking Canvas. Accordingly, in this chapter, we present and justify the methodological definition to carry out these objectives.

Given its practical orientation, our research can be qualified as applied research and more specifically as “practice-led research”, according to Muratovski’s classification (MURATOVSKI, 2015). This author goes on in differentiating practice-led from practice-based research, the first is interested in advancements of knowledge about the practice, while latter has a focus on the artifact developed itself. This explains the need to conduct both studies and consider more than one domain of application for design activity, as we further detail in the following sections.

## 4.1 STUDY 1: COMPARING HUMAN VERSUS MACHINE-GENERATED DESIGNS

In this first study, we need to compare two sets of design concepts, one developed by a human designer and one developed by a computational machine (Design Thinking Canvas Autonomus). In order to do so, we will make use of online questionnaires for data gathering as it enables large scale response with relative low-cost and fairly quick response coding (GRAY, 2013). For each project, all of the evaluators will use Likert scales (ALLEN; SEAMAN, 2007) from 1 and 5 to score the strength of agreement on the following pre-defined list of criteria (previously presented on chapter 2 and 3):

- *Creativity*: the level of novelty and differentiation in the approach to solve the problem in focus.
- *Feasibility*: the level of technical complexity to develop the product.
- *Viability*: the level of business sustainability and attractiveness for the concept presented.

- *Suitability*: the level of alignment regarding all the elements presented for solving the problem under consideration and users´ needs.

This way we intend to make the results more objective and comparable between human and non-human designs. Consequently, we have two independent samples being scored in an ordinal scale. Thus the statistical test that will be used to verify this previous condition and compare both samples is Wilcoxon-Mann-Whitney (MARÔCO, 2011).

Trust among human beings and automated systems is an enormously relevant theme and has multiple perspectives to be considered (CULLEY; MADHAVAN, 2013). Thus, it is important to note that all of the evaluators did not have any knowledge which of the presented concepts were automatically developed by a machine or not in order to avoid any bias during evaluation for all four designs (project A, B, C and D).

### *4.1.1 Sample definition*

As the problems tackled by designers has become significantly complex, not to say that it does not exist anymore, it is more unusual to find the figure of the lone working designer on these projects, or as Brown (BROWN, T., 2009) puts it: "[…] it is common now to see designers working with psychologists and ethnographers, engineers and scientists, marketing and business experts [...]". Thus, our samples will be basically comprised of evaluation results coming from two different groups: [1] digital artifact designers with at least five years of experience; and [2] spontaneous participants from Design Thinking Canvas' Facebook community. Our intention is also to delve into the perspectives of more experienced design specialists to provide more rigorous analysis and of a more general public at the same time, possibly reflecting real-world users of Autonomus' app and as such having the results valuable for them.

Besides developing an overall analysis from evaluation coming from both groups, we will also conduct an analysis considering only experienced designers´ evaluation to check if there is any discrepancy among them in all criteria.

## 4.2 STUDY 2: EVALUATING DIFFERENT LEVELS OF TECHNOLOGICAL SUPPORT FOR DESIGN THINKING CANVAS

A limiting characteristic that comes from the first study is that it only evaluates the design concepts generated (by humans or machine). In practice, a further design activities are still conducted until a final product is developed. The first study sheds very few light on if it helps design teams while tackling real world problems, namely: if the benefits of having technological support for design activity would be confirmed or not, or even if some unintended effects happen during project execution.

Thus, it is also important to investigate how would an agile team perform while using (or not) Design Thinking Canvas Autonomus to develop a product and how it influences their overall results regarding Little Design Up-Front. We intend to address this objective by analyzing two dimensions: process, how does teamwork on design activity unfolds, and product, if the final deliverables reflects the same characteristics obtained on conceptual stages. In order to gain some initial insights on the matter, two different methods have to be setup in order to expand individual results.

For agile project contexts, we will consider two different domains for design activity. We need to do so in order to compare and confirm results and stress the possibility of the influence of the domain itself while applying the methodological variations for Design Thinking Canvas. The common characteristic between both domains is that either way projects must be developed using three different levels of computational support for design activity. We further detail such methodological configuration in the next sections.

### *4.2.1 Sample and projects definition*

In this study, we want to specifically analyze how agile teams would perform to different levels of technological support for conceptual design activities while developing their projects. Accordingly, we segmented possible executions of Design Thinking Canvas methodology in three ways (as shown below). The set of projects to be evaluated must contain at least one of them in each of these levels of technological support for design activity.

1. **Offline**: It reflects a rigorous application of Design Thinking Canvas methodology and all his methods as prescribed in (CALADO *et al.*, 2016; NEVES, 2014) by a team of human designers. Although the name might not be precise in strict terms as some computational support for related activities might be used, the main intention here is to differentiate it from the next two levels that explicitly have some support of Autonomus app for design's methodological aspects. In this case, no direct computational support for DTC was applied. This would be considered our "control group", as the version of Design Thinking Canvas applied here is the foundational one as reported in its main manual by Neves (NEVES, 2014).

2. **Assisted**: in this level, the conceptual design for the product is conceived from a complete step by step interaction from the team with Design Thinking Canvas tool. That is to say, a team of human designers uses all the Design Thinking Canvas Autonomus' database to fill out its project's canvas, as previously described. So, although some human influence and cognition is employed, it only happens in the space of action offered by Autonomus app. Thus, we have a mid-level of technological support in this case.
3. **Automated**: lastly, Design Thinking Canvas Autonomus also offers the possibility to automatically create design concepts with no human intervention. This way, the whole concept of the product to be developed and decision-making process is done by a computational machine so that design team can possibly start product development right away.

Our study will mainly focus on startup-like teams because this type of company have, apart from other difficulties, time-to-market as one of their biggest sources of pressure affecting its development activities (AHREND, 2013). This author also states that "agile" is one of the most associated characteristics with these teams, when compared to large companies' ones, but this feature comes at the expense of running the risk to develop a product that does not match user needs, preventing them to mature. Complementarily, start-up businesses who need more capital investment on its birth has lower chance of succeeding (GELDEREN; THURIK; BOSMA, 2005). In terms of their characteristic, among those companies who are agile practitioners, their top worries are lack of up-front planning (41%) and unpredictability (43.5%) (MELO *et al.*, 2013), which relates closely to our research problem. For all these reasons, that is why the theme of Little Design Up-Front might be relevant for this kind of organization and team structure.

Lindvall (LINDVALL *et al.*, 2002) points out that a team's experience, in terms of technology adopted, field of work and communication skills, can influence their performance within agile methodologies. Thus, it is necessary to stablish a classification criteria for our projects' team in order to meet the blocking principle (DIEZ; BARR; CETINKAYA-RUNDEL, 2012). During this phase, teams under evaluation will be previously assessed under professional experience criteria to avoid biasing factors during project development, which would make them hard to compare to each other.

Besides agile experience, we considered that it would be important to control our agile teams' experience regarding the design methodology that they are going to use in the experiment, Design Thinking Canvas (NEVES, 2014) in this case. Each team will go through a proper training on this methodology by developing a simple project to guarantee they all assimilate its basic concept, sequence and methods. After this training period, their performance will be assessed through evaluation of their results to check the equivalence of their skills.

Finally, each individual team in our sample must be multidisciplinary, comprising of Design and technology competencies considering their domains, to reflect a more common configuration within the desired startup-like world. Considering the possible contexts of our projects, the minimum criteria regarding this topic is that each team must be composed of design and technology profiles that will be responsible for: conceptual definitions, visual identity, interface design and programming of their products.

In summary, the intention is that there is equivalence of: agile and professional experience, Design Thinking Canvas methodology knowledge and multidisciplinarity among samples receiving each type of "treatment" presented in the beginning of this section.

The products created by all these teams, regardless of their domain, must be evaluated by specialist with significant experience in these same domains. The objective is to mitigate the risk of poor understanding during evaluation process and consequently increase reliability on the data generated. Due to his professional experience, the author of this thesis will use his personal networking along with indications from colleagues to enlist proper evaluators to participate during in the questionnaire.

### *4.2.2 Action research setting*

Considering its formatting, this study can be characterized as Action Research (ROBSON, 2002), its main interest is to analyze aspects of influence or change in certain contexts. In our case, the "change" can be said the introduction of different levels of technological support for conceptual design and the "context" is agile project. According to Robson (ROBSON, 2002), Action Research has seven stages for a complete cycle:

1. **Define the inquiry:** describe the research questions – issues, participants, when and where.
2. **Describe the situation**: reflect on the status quo and the actions/tasks that are being conducted.
3. **Collect evaluative data and analyze it:** in the situation under consideration, what is going on?
4. **Review the data and look for contradictions**: contrast what is desired and what is actually happening.

5. **Tackle a contradiction by introducing change:** critically reflect and introduce that is thought to be beneficial to the context under consideration.
6. **Monitor the change**: what is happening as day-to-day activities unfolds while change is introduced.
7. **Analyze evaluative data about change**: how is the situation after the change was introduced as reported by research method.
8. **Review the change and decide what to do next**: define next steps according to the evaluation performed after the change.

In our research, the first four steps for Action Research were addressed by theoretical definitions in each domain under consideration and its related literature review. It enabled us to justify our research focus and define our research question (developed and discussed in chapter 2). Besides the relative novelty of applying Design Thinking within agile projects, the overall action plan for fifth step was laid out by Design Thinking Canvas methodology and Autonomus' description (chapter 3) and more specifically by the presentation of its three variations to be introduced in agile project settings, described in the beginning of this section. The sixth and seventh steps will be conducted through the combination of two methods: Observation (ROBSON, 2002); and Questionnaire, on the same configuration of Study 1, respectively. We further detail both on the next section. Finally, the eighth step will be reflected on the discussion analysis of the data collected during the research.

While choosing Action Research as research methodology, it is also important to acknowledge its limitations, as reported by Gray (GRAY, 2013). To counter the effects reported by this author, our research adopted some strategies to mitigate them (see table 10).

Table 10 – Action Research limitations as reported by (GRAY, 2013) and strategies to mitigate them

| Action Research limitations | Mitigation strategy |
|---|---|
| **Staff turnover**: people leaving the project or context being researched | As it will further be detailed, the agile projects under evaluation happened during one semester of a masters and undergraduate courses, during which we could not identify variations within teams' settings. |
| **Results reporting**: as they are applied within organizational context, sometimes the results are not published in academic literature. | This does not apply to our case, as our main purpose is academic and scientific development for Design field with some publications being already made. |
| **Generalization**: there is a long debate whether results obtained through Action Research can be generalized or not, or even desirable. This happens due to very specific contexts in which the research is conducted. | As we are obtaining the first results from the application of such variation in terms of design methodology, in this phase, our research took a deliberate exploratory stance. It aims to obtain first evidences of such context to further enable other researches and scientific contributions. |

Source: adapted from (GRAY, 2013)

### *4.2.3 Data gathering methods: observation and questionnaire*

In this study, we are interested in two dimensions: process and product. For data collection in this study, we adopted a combination of:

- The author of this thesis has 12 years of professional experience in digital product development, especially within project and product management roles. He was considered to have enough sensibility and background to conduct Observation (ROBSON, 2002) sessions during Sprint reviews from design teams (SCHWABER, 2004; SCHWABER; BEEDLE, 2002). In these weekly meetings, each design team would present partial versions of their products or deliverables. This method allows to collect data directly from the experience observed than through mediated means, which is adequate as in these review sessions each team can share how has its work progressed.

- Online questionnaire using the format of Study 1. Besides the previous criteria, in Study 2´s one we also evaluate other aspects directly tied to Little Design Up-Front, namely:
    - Innovation: as previously described, this concept belongs to creative solutions that happens to perform adequately on the desired market.
    - Product maturity: informs how much close to a commercial launch would a certain product be.
    - Minimum Viable Product: if the product is perceived as testing a clear market hypothesis while being developed with minimal effort.
    - Flexibility to change: if conceptual, visual and technological aspects of each product are capable to be further developed or changed in the face of new opportunities in its market.
    - It is important to note that in Study 1 we had “Feasibility” dimension, which is a prospective variable in the sense of technical complexity to be achieved by the concept when a product is developed. But in Study 2 the same meaning is to be evaluated but as it has been indeed achieved on the developed products, so Feasibility will be referred as Technical Complexity from now on as it makes more sense.

Study 2 will have at least one agile team in each of Design Thinking Canvas configuration (offline, assisted or automated), thus, we have at least three independent samples being scored in several variables in ordinal scale. The most appropriate statistical test for this case is Kruskal-Wallis (MARÔCO, 2011), it will be applied to compare these samples to check if population distributions can be considered equal or different.

For comparisons between Study 1 and Study 2’s results, we will again make use of Mann-Whitman-Wilcoxon test (MARÔCO, 2011) in order to do so under the same reference of statistical test. Also, we will do so under the same criteria (Creativity, Viability, Feasibility and Suitability) as Study 1 only has these.

Before publication for evaluators, Study 2’s questionnaire will be pre-tested through expert review (ROTHGEB; WILLIS; FORSYTH, 2007) comprised by at least: one design specialist, one technology specialist and one business specialist, so that we can combine multiple perspectives of startup-like roles to point out problems of wording and understanding of the questions being presented.

We will also conduct a Focus Group (HANINGTON; MARTIN, B., 2012) with PhD specialists to present our overarching research questions, collect feedback and validate our experimental procedures for Study 2. This can prove valuable in order to give directions for fine tuning our experiment and consequently increase the reliance in our findings.

As the social setting on Study 2 is much more complex than in the first study (several teams and projects being developed), with this combination of qualitative (observation) and quantitative (questionnaire) methods we intend to complement the results from each individual one. Moreover, the point of view of how each one is applied is completely opposite – researcher as observer on the observation and external specialists as evaluators on the questionnaire –, which helps to avoid bias overall.

# 5 EXPERIMENTAL PROCEDURES

As presented in the previous chapter, the experimental part of our research is divided in two studies, one focused on evaluating and comparing conceptual designs developed by humans to others automatically by a computer; and the second going further in evaluating the resulting product of such approach as well. In this chapter, we are going to present operational and contextual aspects of these experimental works. The objective is to present such activities as they unfolded in order to complement the more descriptive approach of the previous chapter.

## 5.1 STUDY 1: COMPARING ASSISTED VERSUS AUTOMATED DESIGNS

Inspired by Turing's classical experiment (TURING, 1950) to check whether a computational machine can sufficiently making itself indistinguishable from another human being, ours one sets out to explore if a machine can provide conceptual design inputs to a level that is equivalent to what a human designer could do itself. We do so by comparing projects developed by a machine and projects developed with human intervention through data selection and multiple-criteria heuristic evaluation for alternative selection. The parallel here is that if a machine can fool human beings into making its designs as relevant as human ones, it can certainly provide enormous contributions to design process and Design as a scientific domain.

The justification to do such test is that design methodologies can be strongly influenced my human capabilities on decision-making. Also, this is a highly regarded topic within agile projects, as shown in a review conducted by Alhubaishy and Benedicenti (ALHUBAISHY; BENEDICENTI, 2017). These researches have also shown that emotion and affect plays an important role on agile teams' decision-making. Design by its turn has developed and investigated several alternative evaluation methods across time (as reported by (CROSS, 2000; LÖBACH, 2001; PAHL; BEITZ, 2013), among others) Thus, we set out to investigate whether a machine can provide more exempt design results in this sense.

### *5.1.1 Experiment setting*

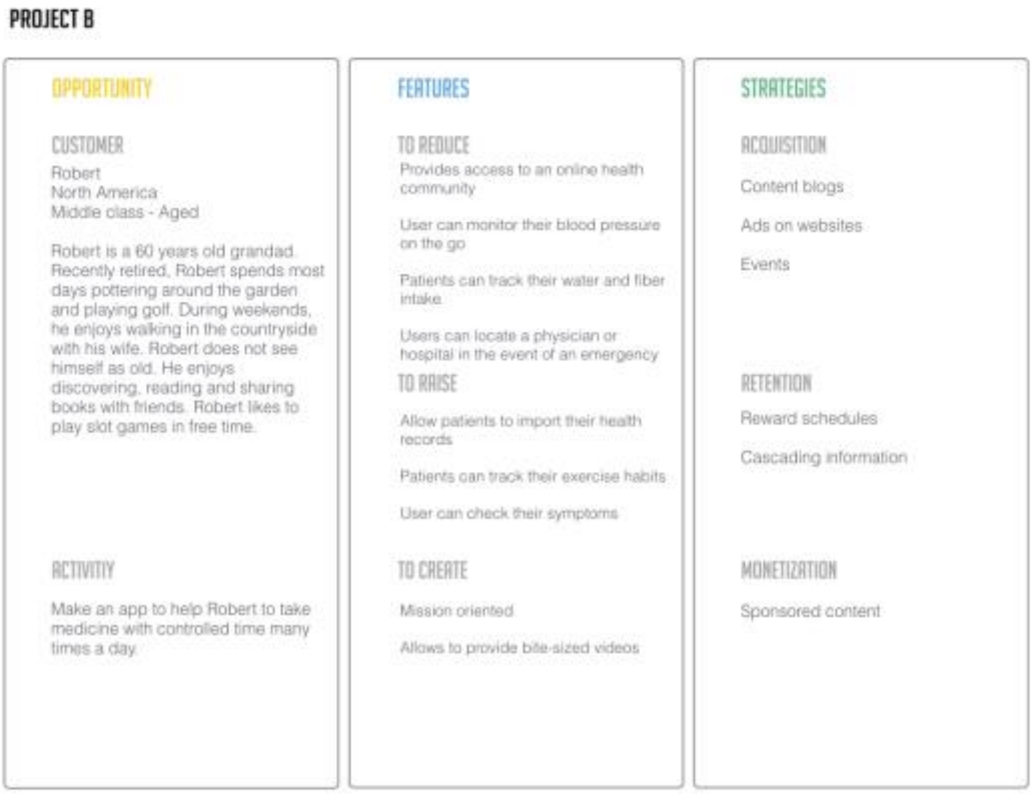
For our experiment, it was used Design Thinking Canvas Autonomus to conceive four apps, each one to a different opportunity. In two of these projects (A and B), an experienced human designer (twenty years of experience) used the app to develop such concepts and in the other two (C and D) the app worked by itself to propose these concepts (see Figure 14-17). As previously described, these projects were evaluated by external evaluators on the criteria composed of: creativity, feasibility, viability and suitability.

Besides being closely related to Design Thinking (BROWN, T., 2009), the selection of these criteria follows the direction stated by Löbach (LÖBACH, 2001) in the sense that design evaluation must be essentially conducted under two dimensions: [1] user/society's interest for the product (broken into creativity and suitability, in our case) and [2] business results for the organization (through feasibility and viability, in our case).

Figure 14 - Sample project A created by human designer in the app


Source: Screenshot from Autonomus app

Figure 15 - Sample project B created by human designer in the app

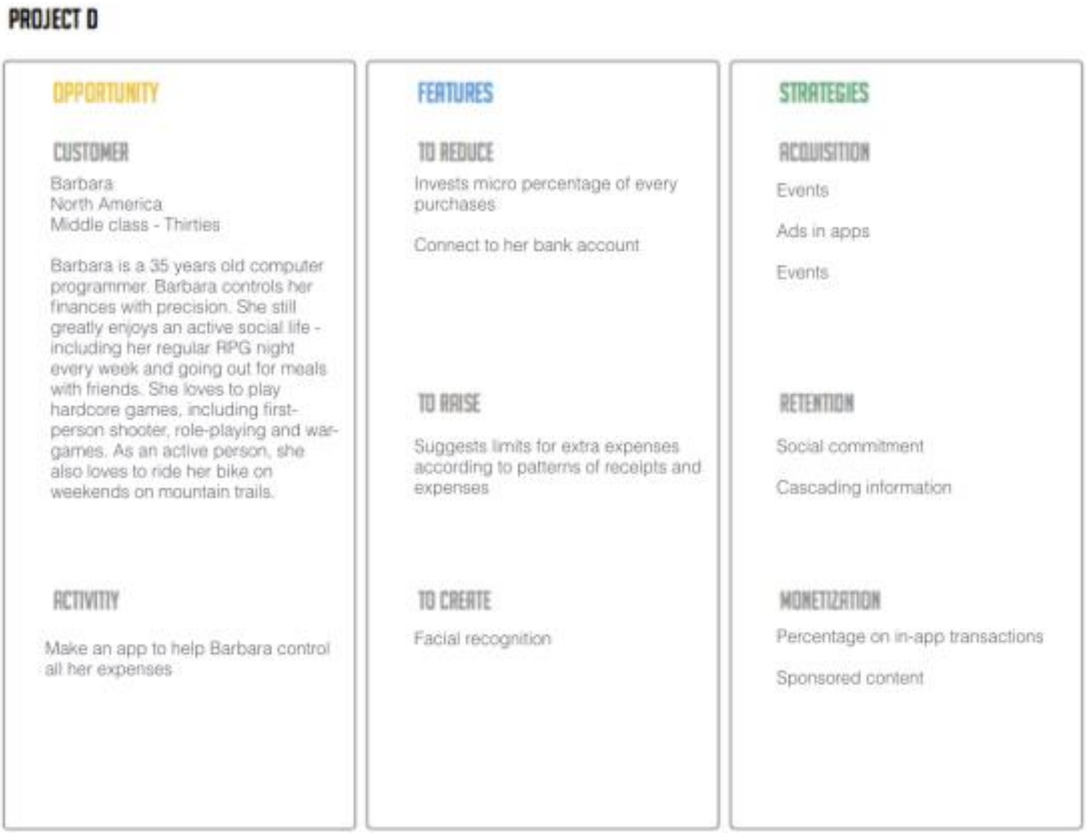



Source: Screenshot from Autonomus app

Figure 16 - Sample project C automatically created by Autonomus


Source: Screenshot from Autonomus app

Figure 17 - Sample project D automatically created by Autonomus




Source: Screenshot from Autonomus app

In order to answer part of our research question, we had to group and compare automated (C and D) and non-automated (A and B) results to check if they had any statistically relevant difference between them. We had these two independent samples being scored in an ordinal Likert scale, the results for the statistical test of Wilcoxon-Mann-Whitney (MARÔCO, 2011) will be reported in the results section in this chapter.

### *5.1.2 Evaluation process*

Using the questionnaire comprised of Likert scales, these four projects were evaluated by a total of 21 evaluators. Considering the groups of evaluators described in the methodology chapter for this first study, after the invitation and their spontaneous participation they could be summed up as: six experienced digital artifact designers (at least five years of experience); and fifteen participants from Design Thinking Canvas' Facebook community. The online questionnaire was open to answers for 42 days, from July 18th to August 31st in 2015.

### 5.1.3 Results from Study 1

In this section, we present and discuss the results from Wilcoxon-Mann-Whitney statistical test regarding the criteria previously presented: creativity, feasibility, viability and suitability. We will first see the overall results considering the total sample evaluations and later we focus on the analysis from specialist designers' evaluation.

Can machines "imitate" humans while developing conceptual designs in Design Thinking Canvas? To answer our research question, we need to check whether the samples show statistically equivalent groups or not. As we stated before, this study intends to compare the performance of an intelligent machine in proposing conceptual designs to a human designer.

So, as hypothesis for our first study's experiment, we say that there is no difference between the evaluation scores for computer generated designs and human ones. To conduct our analysis we used IBM SPSS Statistics software, version 24 ("IBM SPSS Statistics", 2017). To use the non-parametric test of Wilcoxon-Mann-Whitney, we rewrote our hypothesis in terms of the distribution of the scores between human designs group ($X_h$) and computer designs group ($X_c$) for $\alpha = 0.05$ as significance level for a two-tailed test. Thus, we have the following null ($H_0$) and alternative hypothesis ($H_1$) for all the considered criteria:

$H_0: F(X_h) = F(X_c)$

$H_1: F(X_h) \neq F(X_c)$

In the results presented in the following sections, the column for the grouping variable "Designer" is comprised of the values: *Automated* (aggregates results for projects C and D) and *Assisted* (aggregates results for projects A and B) to designate both groups of projects, automated and non-automated conceptual designs respectively.

#### 5.1.3.1 Creativity

What we found for creativity was that the mean rank is consistent with our alternative hypothesis as machine designs value (38.15) is lower than human ones (46.85) (see table 11). But in the test report we can see that the p-value for two-tail is 0.093 which is higher than our significance level (0.05), then we fail to reject our null hypothesis.

Table 11 – Mean rank for Creativity

| Ranks | | | | |
|---|---|---|---|---|
| | Designer | N | Mean Rank | Sum of Ranks |
| Creativity | Automated | 42 | 38.15 | 1602.50 |
| | Assisted | 42 | 46.85 | 1967.50 |
| | Total | 84 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 12 – Wilcoxon-Mann-Whitney test statistics for Creativity

| Test Statistics | |
|---|---|
| | Creativity |
| Mann-Whitney U | 699.500 |
| Wilcoxon W | 1602.500 |
| Z | -1.681 |
| Asymp. Sig. (2-tailed) | .093 |
| Exact Sig. (2-tailed) | .093 |
| Exact Sig. (1-tailed) | .046 |
| Point Probability | .000 |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

From the results, we noticed that we cannot sustain the difference as being statistically significant, although they were borderline, this means that the novelty proposed by both automated and non-automated concepts were equivalent for the evaluators. This is an interesting finding as creativity is usually associated to human factors, especially within design activity, but in this case machine performed as good as them.

#### *5.1.3.2 Feasibility*

Regarding Feasibility, we found that the mean rank is also consistent with our alternative hypothesis as machine designs have lower value (42.31) than human ones (42.69). But in this case the report also shows us that the p-value is 0.947 which is higher than our significance level (0.05). In this case, we also fail to reject the null hypothesis.

Table 13 – Mean rank for Feasibility

**Ranks**

| | Designer | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| FEASIBILITY | Automated | 42 | 42.31 | 1777.00 |
| | Assisted | 42 | 42.69 | 1793.00 |
| | Total | 84 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 14 – Wilcoxon-Mann-Whitney test statistics for Feasibility

| **Test Statistics** | |
|---|---|
| | FEASIBILITY |
| Mann-Whitney U | 874.000 |
| Wilcoxon W | 1777.000 |
| Z | -.075 |
| Asymp. Sig. (2-tailed) | .941 |
| Exact Sig. (2-tailed) | .947 |
| Exact Sig. (1-tailed) | .473 |
| Point Probability | .004 |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Again, due to the absence of statistical strength we cannot support the difference between human and non-human designs. Feasibility is a dimension of utter importance for agile projects as teams usually defers important decisions as late as possible in order to avoid unnecessary commitments early on (POPPENDIECK, M.; POPPENDIECK, T., 2003). Also, discussions over feasibility between designers and software developers is one of the foremost challenges within agile projects (NADIKATTU, 2016). Thus, having the notion of a proper level of confidence in feasibility factor is key to project success.

#### *5.1.3.3 Viability*

In Viability for its turn, the mean rank is consistent with our alternative hypothesis as machine designs has greater value (43.88) than human ones (41.12). The report shows us that the p-value is 0.601 which is higher than our significance level (0.05). Again, we also retain the null hypothesis, and again we cannot find enough statistical evidence for the difference between human and non-human designs.

Table 15 – Mean rank for Viability

**Ranks**

| | Designer | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| VIABILITY | Automated | 42 | 43.88 | 1843.00 |
| | Assisted | 42 | 41.12 | 1727.00 |
| | Total | 84 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 16 – Wilcoxon-Mann-Whitney test statistics for Viability

**Test Statistics**

| | VIABILITY |
|---|---|
| Mann-Whitney U | 824.000 |
| Wilcoxon W | 1727.000 |
| Z | -.539 |
| Asymp. Sig. (2-tailed) | .590 |
| Exact Sig. (2-tailed) | .601 |
| Exact Sig. (1-tailed) | .301 |
| Point Probability | .008 |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Deriving from a Design Thinking, products developed through our target methodology must be created also aiming for its own market sustainability among other dimensions (BROWN, T., 2009). Also, considering the context of agile projects, business value impact is the most mentioned factor to prioritize a certain product feature within project backlog (SILVA, Ana *et al.*, 2017). So, it is important to have this factor in place for both human and non-human designs, which indeed happens as they are equivalent in this experiment. This finding is especially relevant to the objective of addressing Little Design Up-Front as it means that the business vision established by the automated concepts are clear enough to be pursued.

#### *5.1.3.4 Suitability*

Finally, for Suitability the mean rank is also consistent with our alternative hypothesis: machine designs have greater value (45.90) than human ones (39.10). The report shows us that the p-value is 0.188 which is higher than our significance level (0.05). Due to a lack of statistical evidence, we again retain our null hypothesis.

Table 17 – Mean rank for Suitability

**Ranks**

| | Designer | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| SUITABILITY | Automated | 42 | 45.90 | 1928.00 |
| | Assisted | 42 | 39.10 | 1642.00 |
| | Total | 84 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 18 – Wilcoxon-Mann-Whitney test statistics for Suitability

| Test Statistics | |
|---|---|
| | SUITABILITY |
| Mann-Whitney U | 739.000 |
| Wilcoxon W | 1642.000 |
| Z | -1.327 |
| Asymp. Sig. (2-tailed) | .184 |
| Exact Sig. (2-tailed) | .188 |
| Exact Sig. (1-tailed) | .094 |
| Point Probability | .002 |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

As stated previously, suitability factor represents a balance of the elements presented on DTC's canvas while addressing a specific problem. It is not necessary to restate the relevance of the findings of equivalence between human and computer designs for agile project teams. Although they are commonly multidisciplinary, these teams might lack a specific competence or at least have fewer experience in a certain area (e.g. business). Thus, finding that computer designs are as suitable as human ones brings a great possibility of employing this type of aid for design process in the future.

#### *5.1.3.5 Specialist designers' evaluation*

In order to have a particular perspective for comparison, we have repeated the same analysis but this time considering only the cases where we have design specialists as evaluators from our sample. We did so as this group reflect evaluations from those that have more specialized experience in design practice. The objective was to check if there is any significant difference from the previous results, which considered all the cases independent of this segmentation. In the following sections, we detail the results for such group of evaluators.

### *5.1.3.6 Creativity evaluation by specialist designers*

Regarding creativity factor, we found the mean rank comparison consistent with our alternative hypothesis as machine designs value (12.54) is higher than human ones (12.46), but the p-value is 0.986 which is higher than our significance level (0.05). Thus, we retain the null hypothesis.

Table 19 – Mean rank for Creativity according to specialist designers

**Ranks**

| | Designer | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Creativity | Automated | 12 | 12.54 | 150.50 |
| | Assisted | 12 | 12.46 | 149.50 |
| | Total | 24 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 20 – Wilcoxon-Mann-Whitney test statistics for Creativity according to specialist designers

| **Test Statistics** | |
|---|---|
| | Creativity |
| Mann-Whitney U | 71.500 |
| Wilcoxon W | 149.500 |
| Z | -.030 |
| Asymp. Sig. (2-tailed) | .976 |
| Exact Sig. [2*(1-tailed Sig.)] | .977 |
| Exact Sig. (2-tailed) | .986 |
| Exact Sig. (1-tailed) | .493 |
| Point Probability | .000 |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

This again represents an interesting finding for design activity. Specialist designers are usually rigorous with the creative factor as this usually represents one of the most notorious aspects of their work. From the results, we can see that they were "fooled" by Autonomus automatic performance regarding creativity as well. This might represent an initial recognition of the support that computational machines can provide for creative processes.

#### *5.1.3.7 Feasibility evaluation by specialist designers*

For this factor, the mean rank comparison is again consistent with our alternative hypothesis as computer designs score (13.00) is higher than human ones (12.00), but the p-value is 0.763 which is higher than our significance level (0.05). So again, we could not reject the null hypothesis.

Table 21 – Mean rank for Feasibility according to specialist designers

| Ranks | | | | |
|---|---|---|---|---|
| | Designer | N | Mean Rank | Sum of Ranks |
| FEASIBILITY | Automated | 12 | 13.00 | 156.00 |
| | Assisted | 12 | 12.00 | 144.00 |
| | Total | 24 | | |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

Table 22 – Wilcoxon-Mann-Whitney test statistics for Feasibility according to specialist designers

| Test Statistics | |
|---|---|
| | FEASIBILITY |
| Mann-Whitney U | 66.000 |
| Wilcoxon W | 144.000 |
| Z | -.359 |
| Asymp. Sig. (2-tailed) | .719 |
| Exact Sig. [2*(1-tailed Sig.)] | .755 |
| Exact Sig. (2-tailed) | .763 |
| Exact Sig. (1-tailed) | .381 |
| Point Probability | .035 |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

Considering the reported experience of the specialist designers (5 or more years in digital product segment), they are clearly suitable to evaluate the feasibility of the proposed concepts. Thus, it is indeed revealing the findings of equivalence among automated and non-automated designs, possibly meaning that they trust indistinctly on the completion or realization of the proposed products. The implications of this result can be quite useful as it possibly helps to mitigate the fact that feasibility is one of the hottest topics of disagreement between designers and developers, as previously mentioned.

#### *5.1.3.8 Viability evaluation by specialist designers*

In viability, the mean rank is for computer designs is again higher (13.58) than human ones (11.42), but the p-value is 0.478 which is higher than our significance level (0.05). This time again we fail to reject the null hypothesis, meaning we did not find statistical strength to defend otherwise.

Table 23 – Mean rank for Viability according to specialist designers

**Ranks**

| | Designer | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| VIABILITY | Automated | 12 | 13.58 | 163.00 |
| | Assisted | 12 | 11.42 | 137.00 |
| | Total | 24 | | |

Source: adapted from IBM SPSS export (“IBM SPSS Statistics”, 2017)

Table 24 – Wilcoxon-Mann-Whitney test statistics for Viability according to specialist designers

| Test Statistics | |
|---|---|
| | VIABILITY |
| Mann-Whitney U | 59.000 |
| Wilcoxon W | 137.000 |
| Z | -.775 |
| Asymp. Sig. (2-tailed) | .438 |
| Exact Sig. [2*(1-tailed Sig.)] | .478 |
| Exact Sig. (2-tailed) | .478 |
| Exact Sig. (1-tailed) | .239 |
| Point Probability | .035 |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

As previously stated, business dimension is collaboratively constructed and evaluated within Design Thinking process. Although it is not classically expected that designers do so, it is important that they participate in this process, especially experienced ones as our sample. Again, this group of designers could not differentiate automated and non-automated designs in terms of their market prospect.

#### *5.1.3.9 Suitability evaluation by specialist designers*

Lastly, for suitability the mean rank for computer produced designs is also higher (15.46) than human ones (9.54) and the p-value is 0.037 which is lower than our significance level (0.05). In this case, we are able to reject the null hypothesis due to statistical evidence which states that the distribution between the groups are indeed different, with machine automated designs scoring better than human ones.

Table 25 – Mean rank for Suitability according to specialist designers

| Ranks | | | | |
|---|---|---|---|---|
| | Designer | N | Mean Rank | Sum of Ranks |
| SUITABILITY | Automated | 12 | 15.46 | 185.50 |
| | Assisted | 12 | 9.54 | 114.50 |
| | Total | 24 | | |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

Table 26 – Wilcoxon-Mann-Whitney test statistics for Suitability according to specialist designers

| Test Statistics | |
|---|---|
| | SUITABILITY |
| Mann-Whitney U | 36.500 |
| Wilcoxon W | 114.500 |
| Z | -2.167 |
| Asymp. Sig. (2-tailed) | .030 |
| Exact Sig. [2*(1-tailed Sig.)] | .039 |
| Exact Sig. (2-tailed) | .037 |
| Exact Sig. (1-tailed) | .018 |
| Point Probability | .003 |

Source: adapted from IBM SPSS export ("IBM SPSS Statistics", 2017)

This was the most notorious finding of our study as the groups of automated and non-automated designs could indeed could be differentiated, meaning that one of them could perform statistically better than the other. To our surprise, the most suitable ones were design concepts generated automatically by Autonomus. This is especially relevant considering the experience in design field from our sample. We hypothesize that this happened due to the unbiased behavior of Autonomus' algorithm in balancing all of the dimensions from Design Thinking Canvas framework, which does not seem to happen with human intervention. The difference from the previously reported overall evaluation in suitability dimension is possibly explained by the fact that specialist designers, as being more experienced, are more sensitive to a general congruence of the elements from the methodology.

## 5.2 STUDY 2: EVALUATING DESIGN THINKING CANVAS IN ITS DIFFERENT TECHNOLOGICAL VARIATIONS

From the previous study results we could see that, overall, there is no statistical difference between concepts generated by a human designer and Design Thinking Canvas Autonomus app in all considered criteria. As we previously said, albeit relevant in validating Autonomus' conceptual inputs as effective, Study 1's results show only a small part of the whole design process, which usually includes several more steps until products are delivered. Thus, Study 2 have the important role of investigating whether the design work process and the final products created would also result in such equivalent way. To do so, we conducted a second round of experiments by executing the methods described in our methodology chapter.

Two experiments were setup for Study 2. The first one was located at a game development program, which was derived com a research partnership with commercial stakeholders that publishes Warrior Cats book series. These partners proposed a challenge that might interest them in expanding the richness of experience from their books. And another experiment happened within a Multimedia Design program, where the students had workshop sessions for Design Thinking Canvas methodology and later develop a mobile app projects as final results.

### *5.2.1 Configuring agile teams for Study 2's experiment*

As previously defined, Design Thinking Canvas methodology can be executed in three levels of technological support: offline, assisted and automated. In this section, we present how each team was attributed to such levels for experimental purposes and describe intrinsic characteristics and background from their domain.

For accessing startup-like teams as desired by our research, we focused on two programs:

- Game Design and Development masters' program at Universidade da Beira Interior (UBI) (UNIVERSIDADE DA BEIRA INTERIOR, 2017) as contact directory related to our desired sample. This master degree course was founded in 2014 and has been aggregating around 20 students yearly in which they study subjects related to game development and are stimulated to create startup companies focused on gamified or game solutions.
- Multimedia Design course also at UBI (UNIVERSIDADE DA BEIRA INTERIOR, 2017), which is a bachelors-level course that aggregates around 30 students yearly. The focus of this program is to develop student on skills related to digital solutions with a strong background on interaction design, user experience, visual design and usability.

We chose this environment for two reasons: first, we found more openness and support for this experimental setting within these UBI's programs and second, due to the need of executing relatively long projects in order to rigorously contemplate all of its specificities, especially to control internal and external influences (as further detailed in this section). For instance, we wanted to avoid participant turnover or low attendance as this is central to Action Research (as discussed in the previous chapter), so enlisting teams within some curricular courses would help in to control these factors.

### *Game development teams and sample*

Considering the directions established for Study 2's sampling in the previous chapter, our research could enlist 12 students during "Game Design I" course. It is a first-year discipline, where they have to form startup-like teams, including own real names and branding. These teams also have to develop new original projects from scratch during their entire first semester, from September 2016 until February 2017.

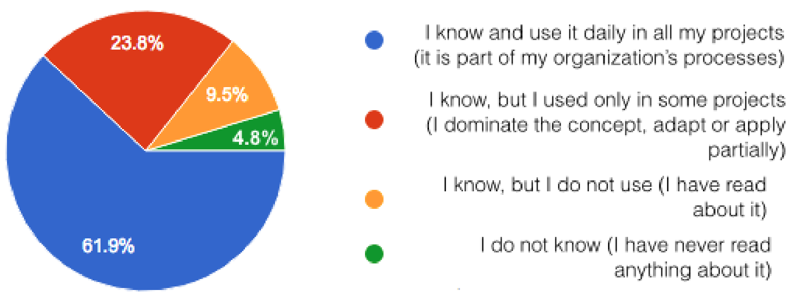
We did an initial assessment where we found that, except for academic projects, none of the students had previous professional experience on game development or Design Thinking Canvas methodology. Then they were asked to spontaneously split themselves in teams under the condition of multidisciplinary formations, which ended up into three teams of four components: one game designer, one user interface designer, one visual artist and one programmer.

After that, all teams were simultaneously trained on Design Thinking Canvas methodology and Scrum framework. The objective was to prepare them, equalize the knowledge and identify any potential discrepancy in terms of team performance.

Finally, for project development, the teams in this setting were randomly drawn to define which one would be selected to each level of the technological support for Design Thinking Canvas: offline, assisted or automated. Also, to avoid influence or cross-contamination among teams during the experiment, some measures were taken: [1] they were instructed not to share information with each other during the project development and [2] during weekly Sprint reviews, where they presented partial results and work in progress, each team had individual sessions with no presence from the others.

For evaluation phase of this experiment, we have sent a total of 29 invitations and got a 74.41% response rate. Thus, the final sample was comprised of 21 evaluators (6 PhDs game-related researchers, 4 business managers, 3 software engineers, 4 game designers and 4 visual designers) with strong professional and academic experience within game development domain. Regarding agile practice, this sample seems quite knowledgeable about the paradigm, with only 4.8% that does not dominate it at least to some extent (see figure 18).

Figure 18 – Agile professional usage by game development experts sample




Source: Created by the author

This high response rate could be achieved thanks to an informal Focus Group (HANINGTON; MARTIN, B., 2012) conducted at Universidade do Minho (Portugal) in June 19th 2017, where 5 PhD participants could be introduced to the background of our research and thesis objectives. These 5 participants stand amongst most qualified Portuguese researchers within game development field. They could give valuable remarks and feedbacks about our experimental procedures, culminating with questionnaire response by all of them at the end of the session.

### *Multimedia design teams and sample*

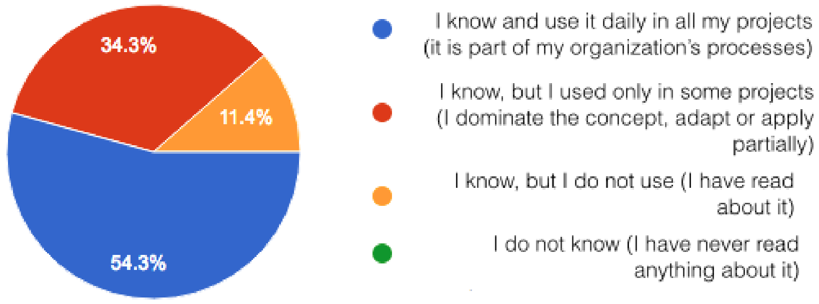
In order to compare the results obtained within game development domain, our research also enlisted designers within Multimedia Design program at Universidade da Beira Interior. The overall spanning time of project execution for these teams was much shorter than the previous one (2 weeks), but at the same time the number of projects and participants was much higher than in game development domain – totalizing 31 students organized in 8 teams (7 teams having 4 participants and 1 team with 3 participants).

Again, team formation was spontaneous among the students, but it was conducted following some previously established criteria in order to provide equality among them, namely: teams must have a maximum of four people and a minimum of three. Also, they should have at least the composition of one interface designer, one user experience designer and one graphical designer, given their professional background. We did again an initial assessment where we found that none of the students had previous professional experience on app development or Design Thinking Canvas methodology. Accordingly, the Multimedia Design teams had a training session of two workshops lasting 4 hours each about DTC methodology.

The attribution of Design Thinking Canvas methodological variations for the experiment was also randomly attributed. In Multimedia Design teams, it was not possible to control cross-contamination among teams, but we do not regard this as problematic. They had very few time for project development: only one day training sessions and already had to deliver the final results in the following week. Also, analyzing the final products we could not detect influence among teams as the concepts developed were completely different from each other.

For this experiment’s quantitative phase, the questionnaire was sent to 84 possible evaluators to which we got a response rate of 40.4%. The final evaluators sample was comprised of 34 participants (14 designers, 8 business managers and 12 software engineers) with considerable professional experience within app and software development domain and strong knowledge of agile practice – all of them know about the subject, only 11.4% does not use it (see Figure 19).

Figure 19 – Agile professional usage by app development sample



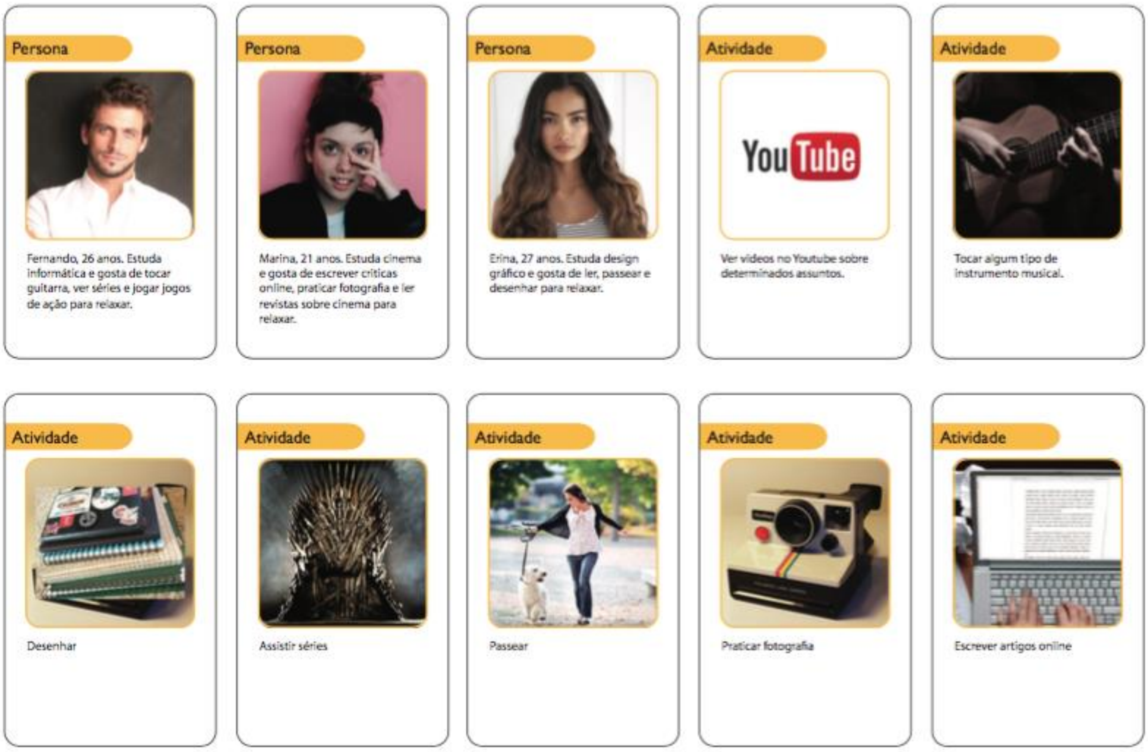

Source: Created by the author

### *5.2.2 Qualitative results: observation of game development agile projects*

Starting the semester on September 21st 2016, Game Design I course schedule had two first introduction session to give on overview of the discipline, introduce the projects and activities for the whole semester, including team formation.

Four weeks into the semester (on October 12th, 2016), all of the 3 teams had their formation in place and could simultaneously start the training on Design Thinking Canvas methodology and Scrum framework, which lasted until November 9th, 2016. It was comprised of 5 sessions (4 hours each), where they could explore theoretical aspects of the design methodology and conduct an exercise project with specific deliverables for each of its phases (see Figure 20 for Persona cards example).

Figure 20 – Persona cards created by Team #3 during training sessions on Observation phase




Source: Screenshot from team #3´s delivered material

The objective of these training sessions was to equalize the students on the understanding and proficiency on Design Thinking Canvas methodology and Scrum agile framework, so the exercises were conducted on hypothetical digital product that each team would freely conceive and they were asked to deliver only visual prototype concepts for their solutions as final results (see Figure 21 for an example).

- Session 1 (October 12th 2016): Introduction to Scrum framework. 9 participants.
- Session 2 (October 19th 2016): Presentation and discussion of DTC's Observation phase delivery. 10 participants.
- Session 3 (October 26th 2016): Co-creative session for DTC's Conception phase. 11 participants.
- Session 4 (November 2nd 2016): Prototype a solution for DTC's Configuration phase. 11 participants.
- Session 5 (November 9th 2016): Final presentation of the training project, including DTC's Publication phase results. 12 participants.

In order to reinforce the importance and seriousness of this training period, the professor conducted formal evaluations in which they were graded on each session. No discrepancy of participation or work quality among teams was detected after all the training sessions. All of the teams presented their results with no delay and were graded as: Team #1: 17, Team #2: 16.66, and Team #3: 16.33, on 0-20 points scale as adopted by Portuguese educational system.

Figure 21 – Final user interface concepts developed by Team #1 during training sessions on DTC methodology


Source: Screenshot from team #1´s delivered material

Following this training period, they started project development where each game design team should employ all of learned methodological skills in order to develop an original game. From all semester activity, this represented the most intense part of their work, especially considering the weight (70%) on their final evaluation on Game Design I course. This aspect reinforces the seriousness of the projects each team would develop.

The design challenge created to motivate all of the teams came from a research partnership that was being established at the time between the Game Design I's professor and publishers of Warrior Cats book series ("WarriorCats.com", [s.d.]). The opportunity of tackling a real market problem seemed to excite the students as most of them are really interested in creating personal portfolio. Also, this validates the context in which this experiment happens for a real-world project with both roles of design team and client/partner present.

The briefing developed was to create a game based on the first book of the series, called "Warrior Cats: Into the Wild", this served as the same input for all of the game design teams, regardless of their DTC's methodological variation for the experiment. Except for this experimental factor, the same instruction was given for all of the teams as they had to comply with, namely:

1. Develop their projects based on the first seven chapters of Warrior Cats: Into the Wild book.
2. Use Scrum as their agile methodology to manage team work until the end of the project.
3. Deliverables:
    a. Game Design Document (GDD) based on Fullerman's template (FULLERTON, 2014), which they could adapt according to each project needs.
    b. Game assets: User interface, arts, animations and audio.
    c. Game Executable: a programmed version of the game specified on the game design document.

No previously established deliverables schedule was shown to these agile teams, as Scrum framework does not prescribe that and also one of the most important aspects would be the analysis of such variation among them. During project development, the observations happened during weekly Sprint reviews that took place on the second half of Game Design I classes, when each team would individually present progress and product increments for each cycle. As previously said, to avoid cross-influence among teams they were separated in this moment with each individual review session lasting around 35-40 minutes every Wednesday.

It is important to note that all of the teams' formation remained stable in terms of individual participants since the start until the end of the semester, a fact of utter importance for an Action Research setting, as justified in the previous chapter.

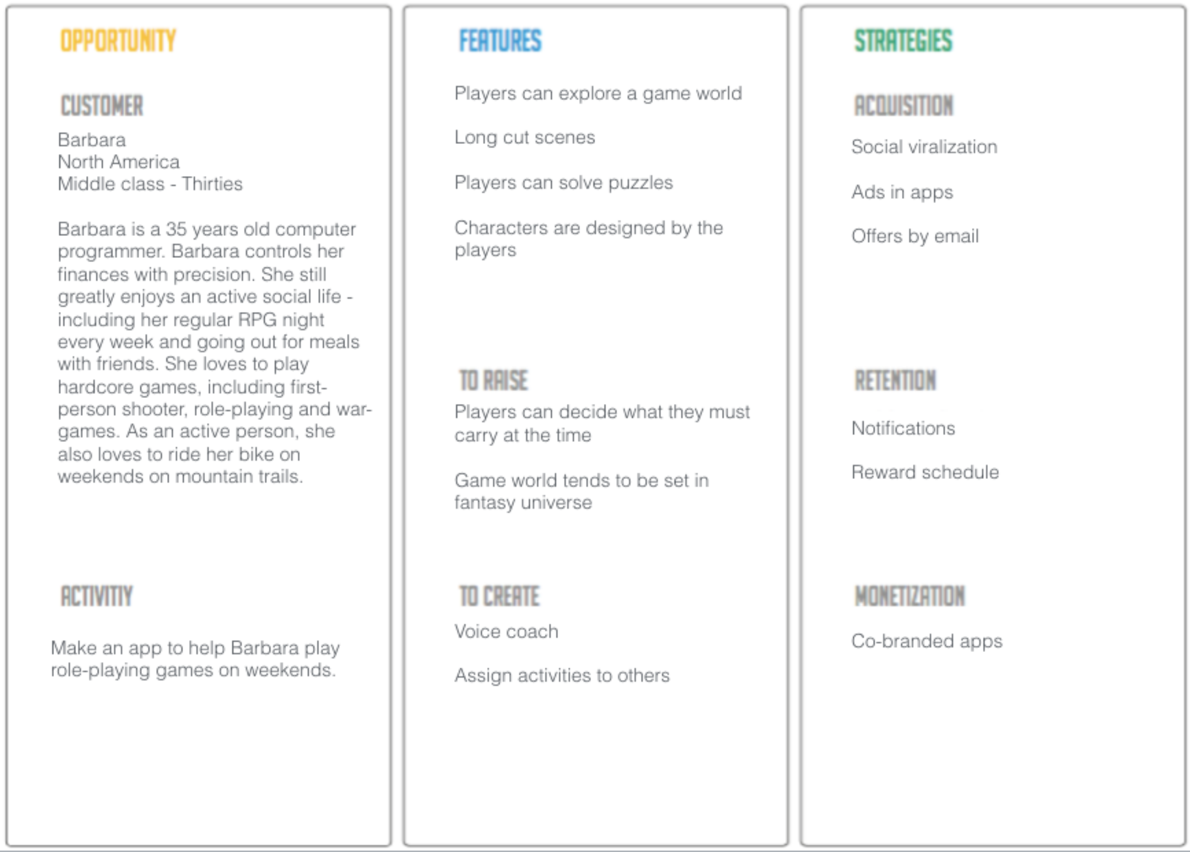
On 16th November 2016, project kick-off was made and the briefing with overall guidelines was presented for all students. Then, the game design teams were randomly drawn to define which version of Design Thinking Canvas technological support they would use, after this process the distribution was: Team #1 – *Assisted*, Team #2 – *Offline*, Team #3 – *Automated*. The drawing was public to all students, but the attribution was informed only to each team individually, so they had no idea of each version DTC version the others were working. Also, during kick-off, a digital version of Warrior Cats: Into the Wild book was handed to all participants and an iPad with Design Thinking Canvas Autonomus app previously installed was made available so that Team #1 (Assisted) and Team #2 (Automated) could use it to define their game concept.

From now on, instead of numbers we will use the name of their own corresponding DTC scenario to make it easier to understand and recall which one we are referring to, this way: Team #1 becomes “Team Assisted”, Team #2 becomes “Team Offline” and Team #3 becomes “Team Automated”.

In the following week (23rd November 2016), the first Sprint review meetings were individually conducted. Team Automated could already define and discuss the conceptual design for their game during the meeting (represented by the canvas shown in Figure 22). The conceptual design for Team Assisted for its turn could not be defined in this first meeting. They did some considerations and explored Autonomus app during most of the meeting, only to decide that they should have more discussion before making the final choice from its database. Finally, Team Offline started to plan the investigation of contextual information for Observation phase from Design Thinking Canvas, they only presented some initial ideas of what might be their focus.

On the week of 30th November 2016, the students could not meet physically to have the Sprint Review as they had to participate on an external event on the university. Still, they reported some progress remotely: Team Offline had already conducted some field observations and Team Automated had already started to develop their Game Design Document then. Team Assisted reported that they have made a decision about their chosen conceptual design after selecting the options from Autonomus’ database and heuristically evaluating it with the app.

Figure 22 – Canvas for the automatically created conceptual design by Autonomus for Team Automated




Source: Screenshot from team Automated delivered material

In the next Sprint review (December 7th 2016), Team Assisted presented their canvas, but also started to report some concerns with their chosen conceptual design of a utility app. Although they themselves decided for it, they considered it to be really challenging to have a functional app as a concept, which they would still have to gamify. Team Assisted ended up deciding to retract such design concept a few days later (we will further detail this issue). Team Offline presented the first results from Observation phase, but could not complete their competitors benchmark, as prescribed by Design Thinking Canvas methodology. This lapse was noticed by them and justified by the lack of time. It was decided that this data and overall improvements for this initial research should be presented in the next Sprint. Finally, Team Automated already presented the first version of their Game Design Document on December 7th 2016 and delivered it in the next day. During this week's review, they could extensively discuss and present the progress so far. Although the document was still a draft with some incomplete sections, it already included some visual assets and a schedule planning, among other things (see Figure 23 and Table 27). The description stated in the document was a RPG game that reflected initial passages from the Warrior Cats' narrative, when the protagonist abandons its home to become a wild warrior for Thunder Clan.

Figure 23 – Visual sprites for game characters by Team Automated

Source: Screenshot from team Automated delivered material

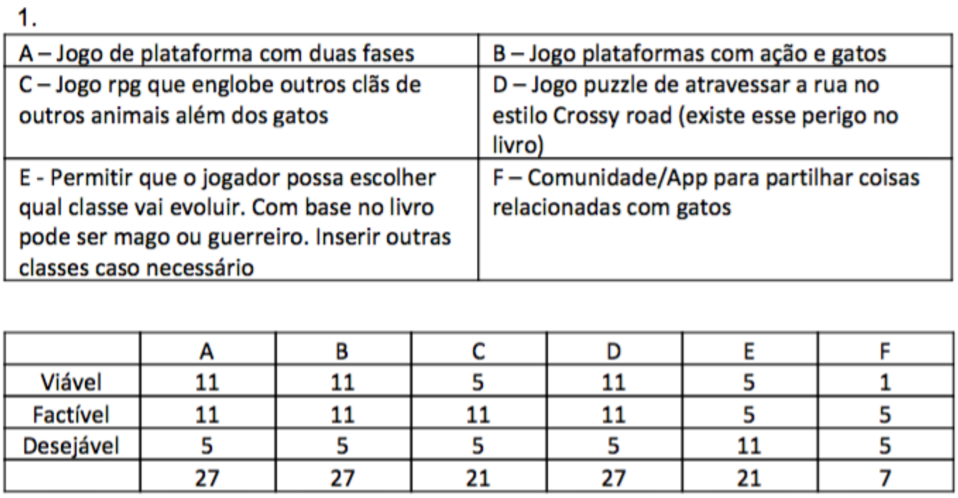
Table 27 – Project schedule excerpt presented on Team Automated's Game Design Document

| | November | | | | December | | | | January | | | | February | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task/Sprint** | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | **Status** |
| Write GDD draft | | | | | | | | | | | | | | | | | Complete |
| Present GDD | | | | | | | | | | | | | | | | | In progress |
| Select and draw characters' art | | | | | | | | | | | | | | | | | Planned |
| Select and draw scenarios' art | | | | | | | | | | | | | | | | | Planned |
| Develop player's control system | | | | | | | | | | | | | | | | | Planned |
| Develop map system and levels | | | | | | | | | | | | | | | | | Planned |
| Implement collision detection | | | | | | | | | | | | | | | | | Planned |
| Develop score system | | | | | | | | | | | | | | | | | Planned |
| Implement enemies | | | | | | | | | | | | | | | | | Planned |

Source: team Automated delivered material

Prior to the next Sprint review (December 14th 2016), Team Assisted indeed decided to change their design concept after some careful consideration and, on December 12th 2016, they remotely communicated of this new direction by sending a canvas describing their new conceptual design that would base their work. Thus, their participation in this week's review meeting was mostly occupied in justifying such decisions and why it would be better to do so. Even a report trying to align Warrior Cats' narrative to this new concept was presented and sent along with the canvas. Team Automated, for its turn, continued a much more advanced project evolution and presented an updated version of the Game Design Document. It filled all the incomplete sections from the previous week and with more progress from visual assets, namely: overall map and levels. They also presented the RPG Maker software to support their programming activities. Finally, after completing the Observation phase entirely, Team Offline reported the progress finishing the Conception phase in this current sprint. They presented the overall results from co-creative sessions consisting of 36 ideas, which they ranked and selected through Design Thinking Canvas heuristics and summarized the best ones to compose their high-level concept for the game. A report detailing all this data was delivered on December 16th 2016 (see figure 24).

Figure 24 – Sample of idea generation board and heuristics selection scores by Team Offline



1.

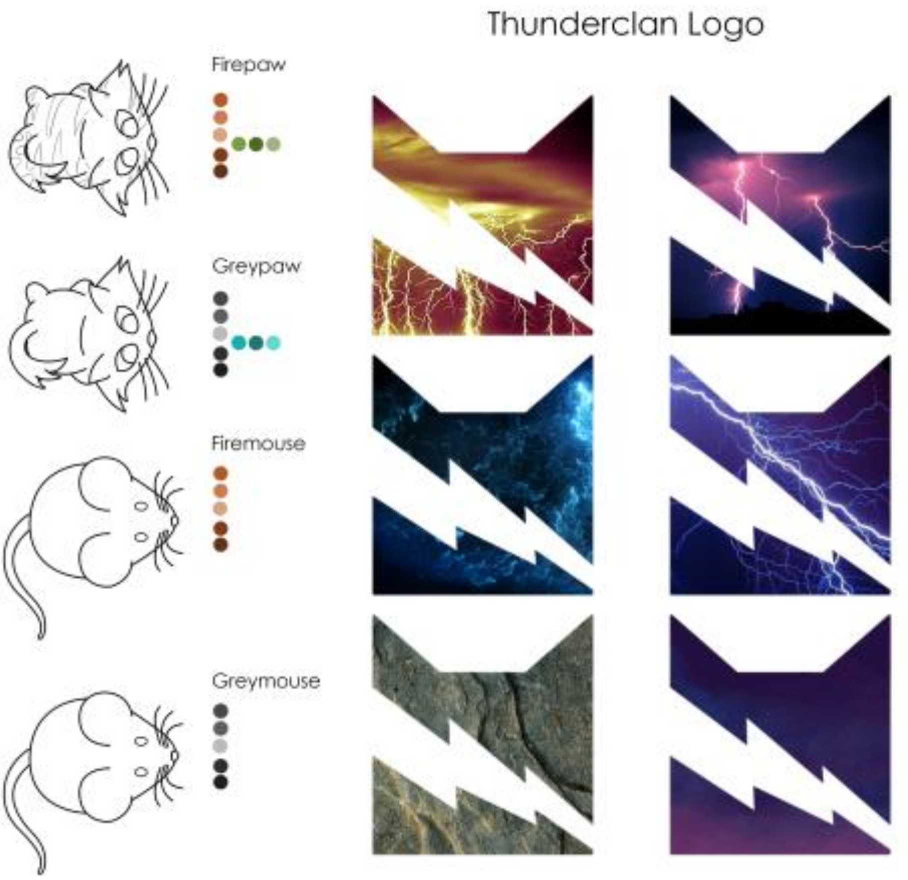
| A – Jogo de plataforma com duas fases | B – Jogo plataformas com ação e gatos |
|---|---|
| C – Jogo rpg que englobe outros clãs de outros animais além dos gatos | D – Jogo puzzle de atravessar a rua no estilo Crossy road (existe esse perigo no livro) |
| E - Permitir que o jogador possa escolher qual classe vai evoluir. Com base no livro pode ser mago ou guerreiro. Inserir outras classes caso necessário | F – Comunidade/App para partilhar coisas relacionadas com gatos |

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Viável | 11 | 11 | 5 | 11 | 5 | 1 |
| Factível | 11 | 11 | 11 | 11 | 5 | 5 |
| Desejável | 5 | 5 | 5 | 5 | 11 | 5 |
| | 27 | 27 | 21 | 27 | 21 | 7 |

Source: Screenshot from team Offline delivered material

For the next two weeks (from December 20th 2016 until January 2nd 2017), the students did not have any class as the university entered in its holiday season, which blocked any possibility of observation during Sprint reviews in the period. Although it was not planned any activity for the period, Team Assisted communicated and delivered a first draft of their Game Design Document on December 19th 2016, containing very basic descriptions of: the narrative theme, game mechanics and an analysis of its game balancing. They complemented this GDD with some very initial art concepts (team logo and basic character sketches with color palette, see figure 25) delivered right on the following day (December 20th 2016). On December 27th 2016, Team Offline just reported (but not delivered) that their Game Design Document draft was still being developed.

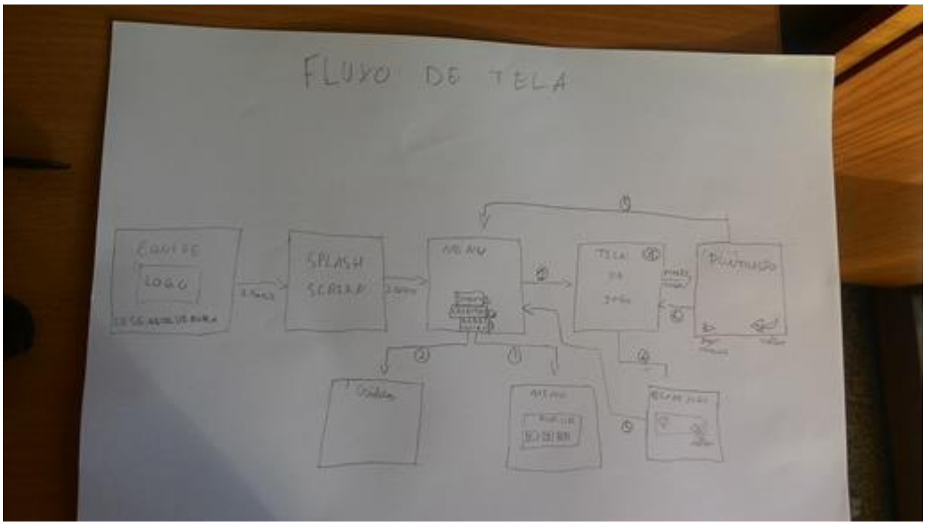
Figure 25 – Character sketches with color study and logo alternatives by Team Assisted




Source: Screenshot from team Assisted delivered material

Back from the holidays, there were only 2 weekly Sprints remaining until the end of the semester. In the Sprint review of January 4th 2017, Team Assisted presented and delivered another updated version of their Game Design Document, which has detailed internal descriptions and included sketches for the game flow (see figure 26). They have also presented some of the assets to be integrated in the final product. Team Automated demoed part of its implemented prototype although some visual assets were still missing. For the first time, Team Offline presented a version Game Design Document, even though there was only the final presentation left in the semester. No visual support or assets were delivered along with this team's GDD, only textual descriptions.

Figure 26 – Rough screen flow sketches attached by Team Assisted




Source: Photo from team Assisted delivered material

The final presentation for the semester happened on January 11th 2017. It was a public session held at Game Development Lab, where each team had 30 minutes to present a summary of their activities since the beginning of the project and pitch their final games. After all the presentations and comments were elaborated by the professors, each team setup a computer to demo their final game products so the audience could experience their games.

Team Offline, which used the basic version of Design Thinking Canvas, developed a game (see figure 27) that mixes two established mechanics: platformer and tower defense, where you should protect your left base from advances from the enemies while moving around the scenario and attacking them with a sword and an arrow. Besides the life limit the player is also limited to a number of enemies that can be allowed to invade your base, if any of these is exceeded the current level is restarted. They currently developed only one level.

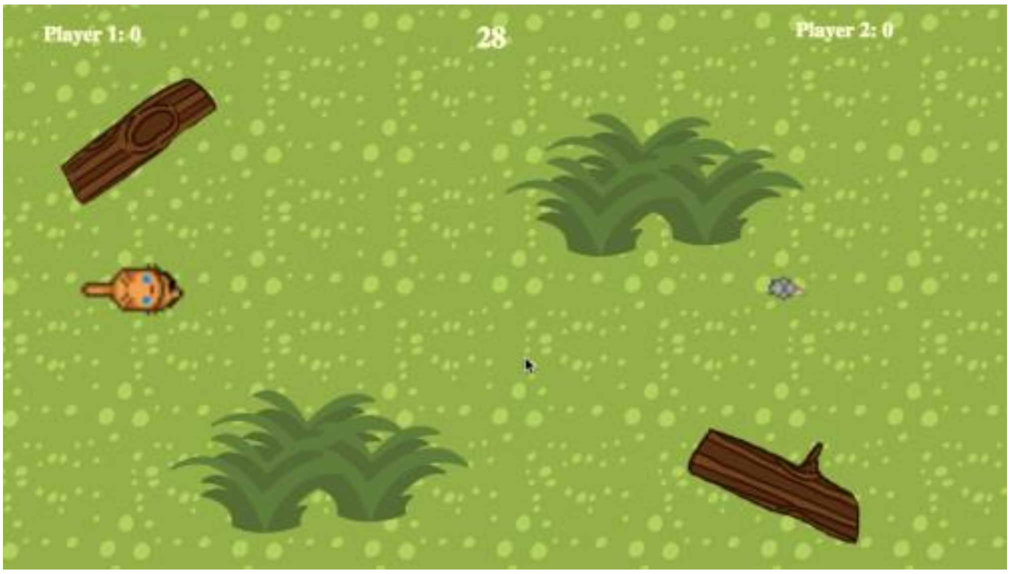
Team Assisted, which used DTC Autonomus to assist their conceptual design generation and decision-making, developed a game that consists of a turn-based battle for two simultaneous players (see figure 28). The player 1 has a time limit during which she assumes the role of the cat and must run after and capture the mouse (player 2) the most she can, after this period of time the cat-mouse roles between the players are inverted. After this second round, the total number of captures is counted and the one with the highest number wins the battle. As with the previous team, they only developed one level for the game.

Finally, Team Automated, which used Autonomus to automatically conceive their conceptual design, developed a RPG game (see figure 29) that follows the really successful, but consolidated, path from big players in game industry, like Pokémon Red and Final Fantasy (“Final Fantasy (video game)”, 2017, “Pokémon Red and Blue”, 2017). In this type of game, the player freely explores a 2D map where she encounters enemies and objects that can be collected to help later in the game (e.g. weapons or food). The progression is measured in experience (XP) that is based on how successful the player has been in the missions she faces. The battle is turn-based where the player chooses an action (e.g. attack or run) and the computer-controlled opponent counterattacks (e.g. defend or recover life). Each opponent does not know beforehand the action chosen by the other and the efficiency of such action is based on the counterattack chosen by each opponent. The one that loses its total life first loses the battle. Team Automated developed three scenarios: house, backyard and a forest glade.

Figure 27 – Gameplay screenshot from the game by Team Offline


Source: Screenshot from team Offline delivered material

Figure 28 – Gameplay screenshot from the final game by Team Assisted




Source: Screenshot from team Offline delivered material

Figure 29 – Gameplay screenshot from the final game by Team Automated


Source: Screenshot from team Automated delivered material

After final presentation, all teams delivered a package containing the final game products and some updates to their Game Design Documents and assets. Curiously, after careful analysis of such artifacts, all teams presented future possibilities for their games during their pitch although they have not been asked to do so, which means that at least to some extent they have embedded the principle of Little Design Up-Front on their products.

They presented possible future evolutions of their games. We give some visual examples in Figure 30-33.

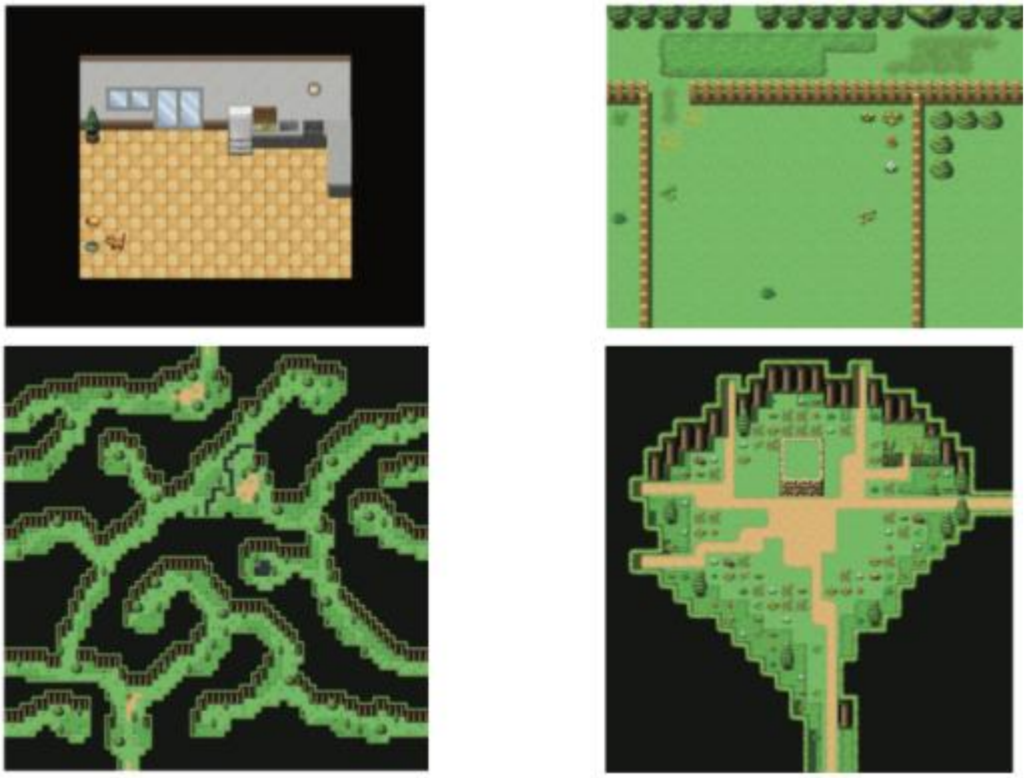
Figure 30 – A comparison of the game demo delivered (left) and the future desired state (right) by Team Assisted


Source: Screenshot from team Assisted delivered material

Figure 31 – More character variations from the game demo (left) to other options not included so far (right) by Team Offline

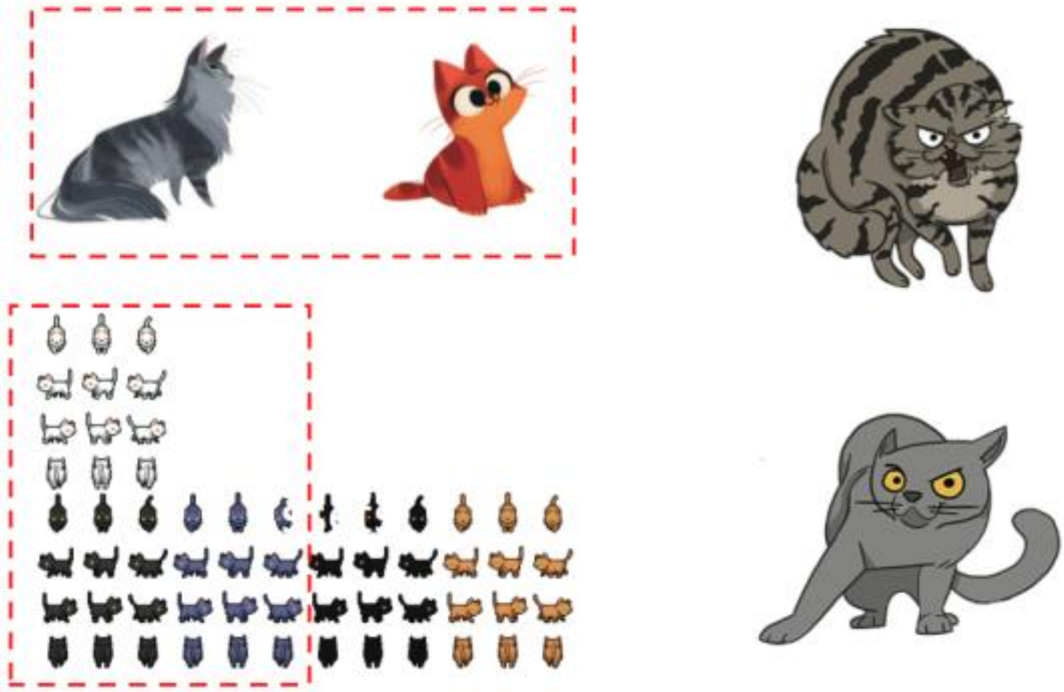
Source: Screenshot from team Offline delivered material

Figure 32 – Game world and level expansions (bottom-left) by Team Automated



Source: Screenshot from team Automated delivered material

Figure 33 – Characters visual evolution and expansion (marked in red), according to the narrative by Team Automated



Source: Screenshot from team Automated delivered material

Except for Team Assisted that used the indie platform Itch ("Itch.io", [s.d.]), none of the other teams published their games. They alleged some technicalities and lack of access to licensed premium accounts on any of the most famous app/game stores (e.g. Apple's App Store or Steam), which prevented them to make their final product available for end users.

### *5.2.3 Qualitative results: observation of multimedia design agile projects*

The observation for Multimedia Design context happened during May 26th 2017, when took place a 8 hours workshop (from 9:00 until 18:00) for Design Thinking Canvas methodology. This was developed as part of the Seminar and Workshop II course, which is a third-year discipline for Multimedia Design bachelor's program. It had an audience of 31 participants.

The same design challenge was proposed to all teams, which consisted that they should conceive an innovative digital product considering the problem, market and persona being addressed, regardless of their Design Thinking Canvas methodological variation. As project deliverables, the professor defined that they had until Jun 6th 2017 (11 days) to develop:

1. Conceptual design based on Design Thinking Canvas Autonomus app's canvas template.
2. Visual identity for the product and its user interface.
3. Interactive prototype using Adobe Experience (ADOBE, [s.d.]).

Design Thinking Canvas workshop was divided in two sessions. In the morning, the whole theory, phase concepts and methods for the methodology was presented and discussed, the students could participate and clarify any doubts. In the afternoon, a practical session of the methodology took place. The students were asked to spontaneously split themselves in teams of 3 or 4 participants, having at least one user experience designer, one user interface designer and one graphical designer. For experimental purposes, regarding the level of technological assistance for Design Thinking Canvas, teams were randomly drawn into the three levels, as previously explained. It led to the following distribution:

- Offline: 3 teams (Team #1, Team #6 and Team #8)
- Assisted: 3 teams (Team #2, Team #5 and Team #7)
- Automated: 2 teams (Team #3 and Team #4)

As with game development teams, Multimedia Design teams' formation remained stable during the whole experiment with no individual inclusion, exchange or exclusion within them. The only fact to report in this sense is that on May 29th 2017 two students asked to form a ninth group and develop the proposed work even though they did not participate in the workshop sessions, but they were not allowed to do so and discarded from experimental purposes.

In order to balance time available and effort size, these three groups received practical orientations in a specific order. The first group to have individual instructions in the afternoon session was the Offline one as they had much more manual work and research to proceed, so being the first would allow them to better equalize knowledge and have more time for clarifications. During this period of time, Offline teams could explore examples and practical application of the methods prescribed by Design Thinking Canvas methodology, they finalized this session by executing Brainwrite 6-3-5 method for idea generation and evaluating them through heuristics, as prescribed by Design Thinking Canvas methodology. Team #8 was the most engaged one in this group, their participants would always be asking questions, while Team #1 seemed more knowledgeable in applying the methods and was able to conduct and would even synchronize the clock timer during Brainwrite execution for all teams. Team #6 was more hesitant while applying the methods but was able to carry on the activities.

Due to the mid-level support from DTC Autonomus app, the second group to receive practical instructions was the Assisted one. These teams used the time to learn how to use Design Thinking Canvas Autonomus app and understand the whole flux to create their conceptual designs and use its heuristics feature to evaluate each block. Two Apple iPads were made available to these teams. Thus, Assisted teams could spend the practical session using them to explore Autonomus possibilities as much as they considered necessary. Team #2 finished the task to define their conceptual design quite fast while using DTC Autonomus app, after that they seemed a bit uneasy and constantly asked what they should do next. On the other hand, Team #7 had some doubts while using the app and could only understand heuristics evaluation when they were individually explained for the second time. Team #5 had some initial doubts about the app in the beginning but was able to move on.

The third and last group was the Automated one that received instructions about the structure of the canvas and clarification on the concepts presented. As these teams did not spend much time while defining their design concepts, they were instructed to further discuss them in order to create shared understanding. All Automated teams went further in such task and developed wireframes or some initial user interface sketches. While doing this, team #4 had some doubts in understanding a feature that indicated “support hardware integration”, which they creatively solved by suggesting an integration with a smartwatch. Team #3 also showed some doubts about a feature existent in their concept regarding “automatic investment according to expenses”, they defined that as investment it was going to be considered a saving account associated with the persona’s bank account due to its profile.

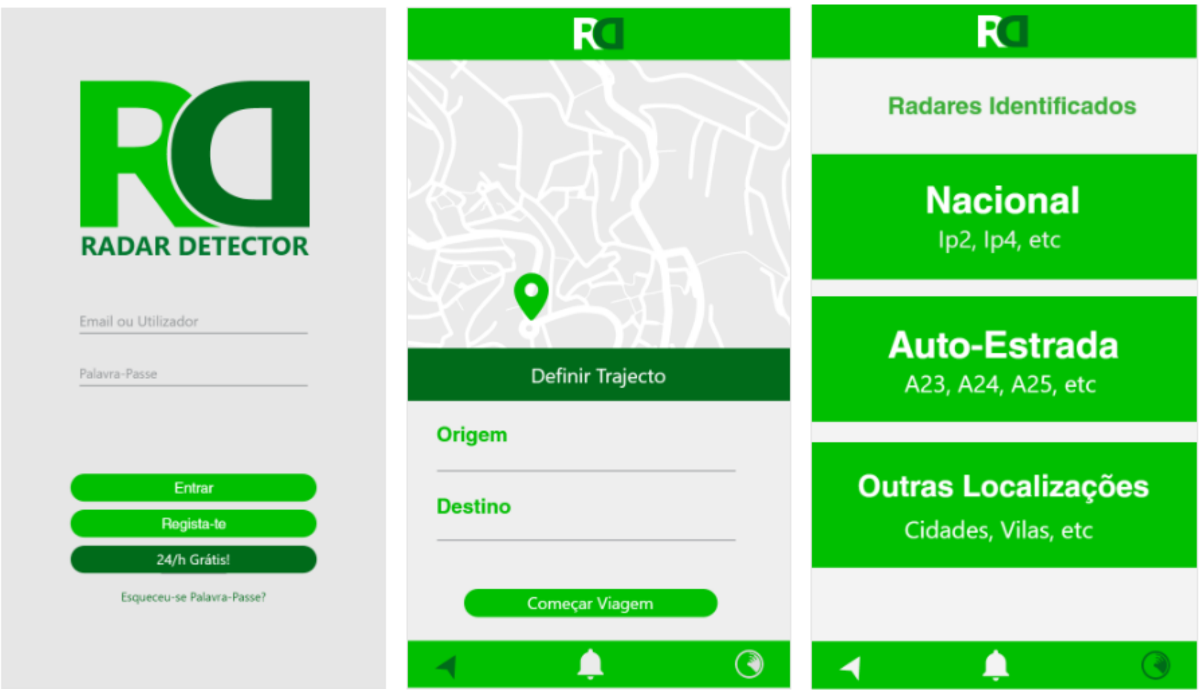
After eleven days since the training workshop, all teams would supposedly deliver their final results on 6$^{th}$ June 2017. On this subject, the first team to deliver results was Team #3 (an Automated team) on June 5$^{th}$, one day prior to the defined deadline. The only detected delays were made by Team #8 and #1, interestingly, both Offline teams. They delivered their final work on June 7$^{th}$ 2017. All other teams respected the normal deadline.

The results delivered by teams executing the basic version of Design Thinking Canvas (Offline) were:

- Team #1: they developed an app called Radar Detector (see Figure 34) that would be a tool to directed to young people so they could avoid speed tickets while driving through selected routes.

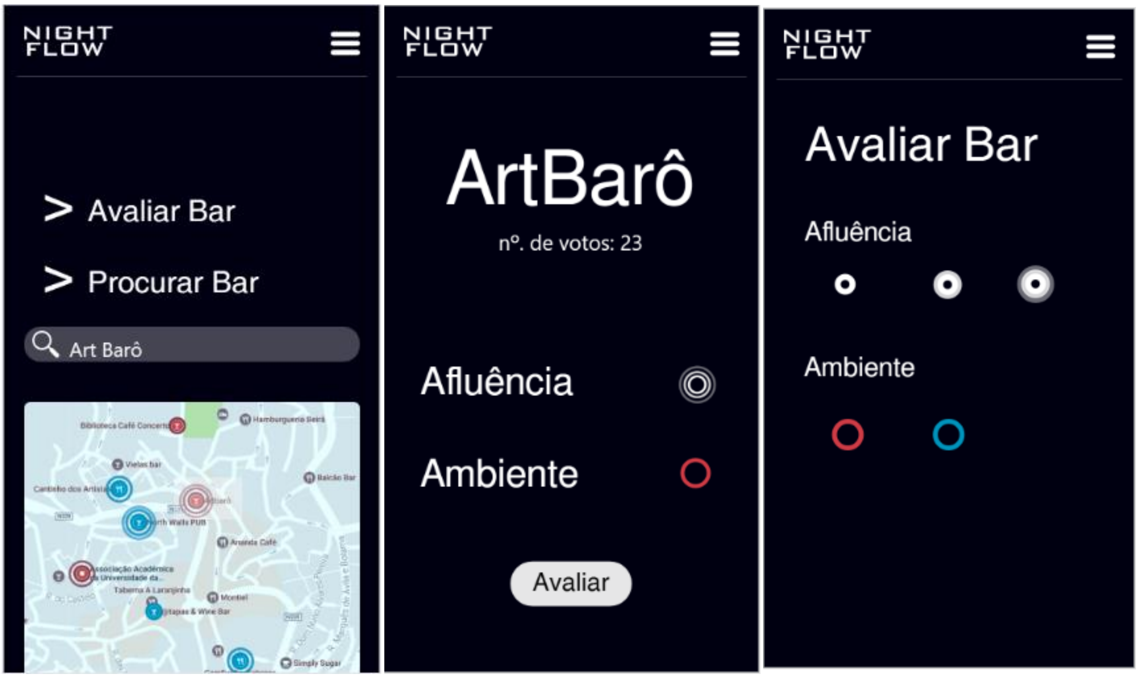
- Team #6: this team developed Night Flow app (see Figure 35) that proposes to be a solution that allows its users to search and evaluate bars and nightclubs and verify their allotment as well.
- Team #8: their app is called Arion (see figure 36), which stands as an audio streaming service where new bands can showcase their work. Users can search and explore the whole music collection and favorite some of them to build a personal collection. Besides the prototype, this team also delivered all its visual assets and a justification for the app naming.

Figure 34 – Screenshots from Team #1's app: Radar Detector



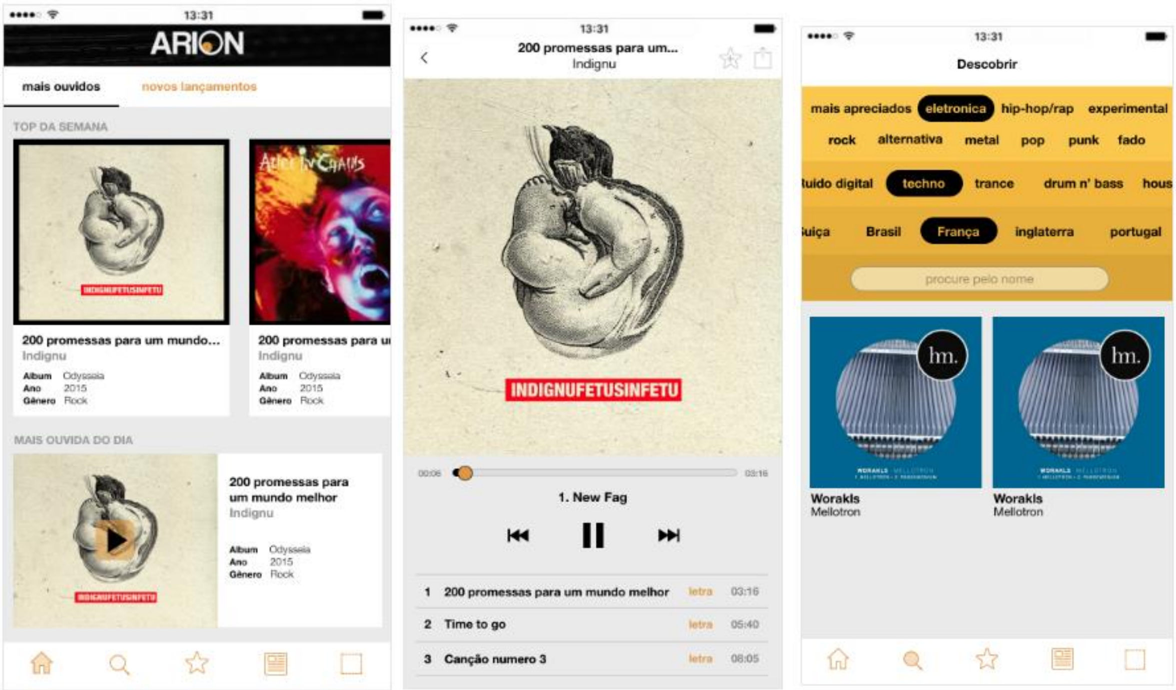

Source: Screenshot from team #1´s delivered material

Figure 35 – Screenshots from Team #6’s app: Night Flow




Source: Screenshot from team #6´s delivered material

Figure 36 – Screenshots from Team #8's app: Arion




Source: Screenshot from team #8´s delivered material

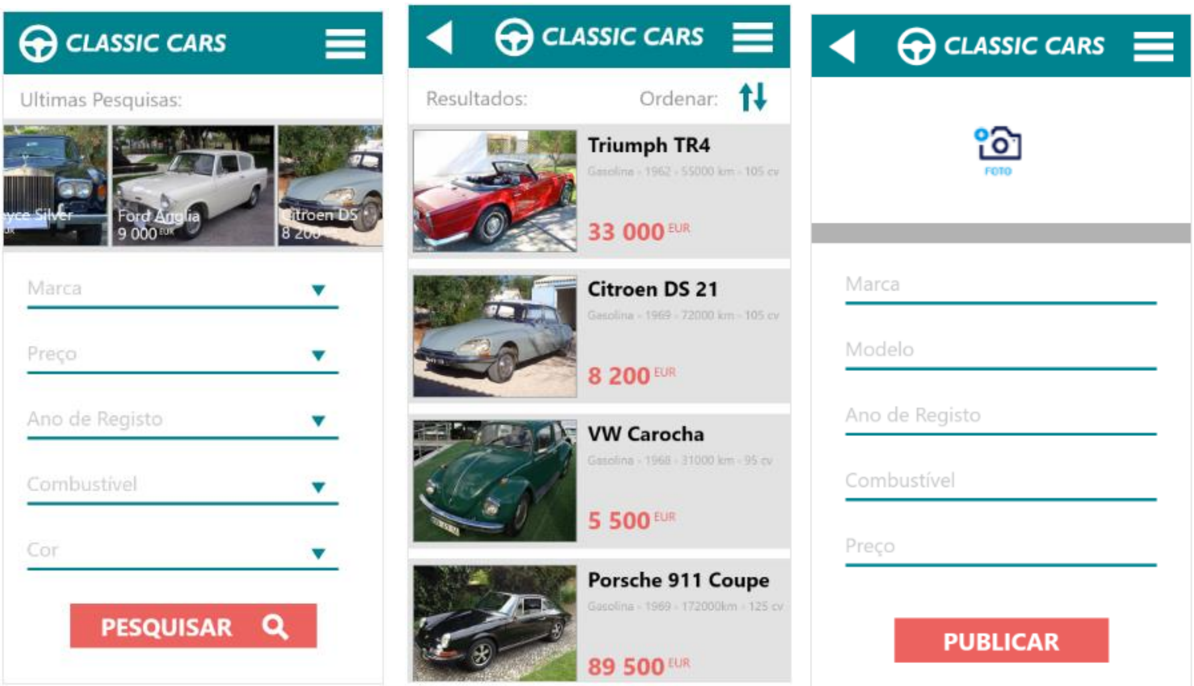
Teams assisted by Design Thinking Canvas Autonomus (Assisted group) developed the following solutions:

- Team #2: in Classic Cars app (see Figure 37), its users can find a marketplace for classic vintage cars, where they can search and publish selling options and also communicate with car sellers.
- Team #5: this team developed an app called Protect Sun (see Figure 38), which stands as a way to define the level of sunscreen to be applied by the user depending on its current location and personal characteristics. After analyzing the canvas developed with the app it is possible to note that Team #5 diverged a lot from the original proposal. We could not report the reason why this happened as no observation was possible to conduct on intermediate deliveries during product development, due to the short timeframe of this experiment. The design concept initially developed with assistance from

Autonomus was focused on a solution to help daily medicine in-take management, which clearly is not reflect on the prototype delivered.

- Team #7: GlobalMov app (see Figure 39) represents a way to assist movie goers, where these users can buy tickets, watch trailers and streaming and read movies-related news. Its novelty is that there is a worldwide synchronization for movies content. Without being asked to this team delivered a report that gives context to the app, naming, typography and also presents a brief wireframe study for the solution.

Figure 37 – Screenshots from Team #2's app: Classic Cars

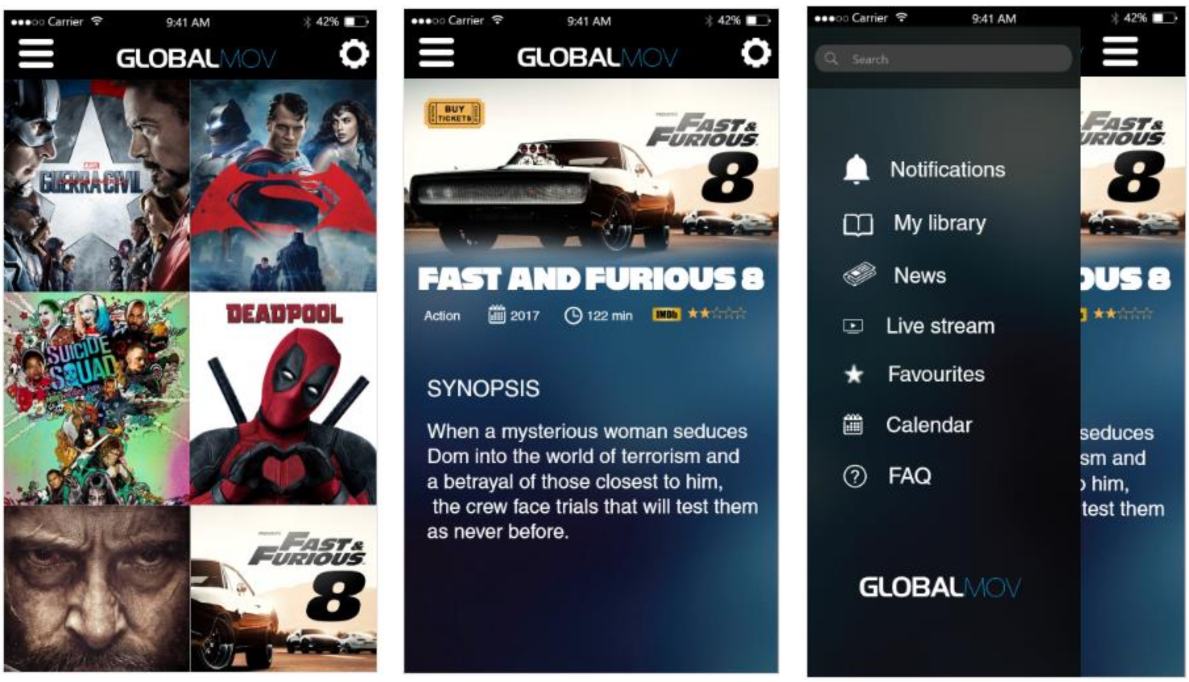



Source: Screenshot from team #2´s delivered material

Figure 38 – Screenshots from Team #5's app: Protect Sun


Source: Screenshot from team #5´s delivered material

Figure 39 – Screenshots from Team #7's app: GlobalMov




Source: Screenshot from team #5´s delivered material

Finally, for the teams that used automatically generated design concepts by Design Thinking Canvas Autonomus (Automated group), we had:

- Team #3: PigHelper (see Figure 40) is an app that assists its users to control their expenses when linked to their bank account. They can define a percentage of automatic savings or follow a suggestion automatically given by the app based on previous expenses patterns. This team was the only one that iterated on their solution as they delivered it earlier than the final deadline, some minor adjustments were included and the prototype was updated.
- Team #4: this team developed Cantinho da Quinta (see Figure 41) which stands as a resource management social game. In this app, the user has to manage a farm where she can buy or grow crops and feed animals. Without being asked to, this group also delivered a report detailing the solution, where, besides app screens, it is also possible to see an integration to smartwatches (see Figure 42). This was the only team that presented a solution that went beyond a mobile app itself.

Figure 40 – Screenshots from Team #3's app: PigHelper


Source: Screenshot from team #3´s delivered material

Figure 41 – Screenshots from Team #4’s app: Cantinho da Quinta

Source: Screenshot from team #4´s delivered material

Figure 42 – Team #4’s Cantinho da Quinta integrated to a smartwatch


Source: Screenshot from team #4´s delivered material

### *5.2.4 Quantitative results from Study 2: Intro*

As explained in the Study 1’s experiment, in this one the evaluators also did not have any knowledge about level of computational support that each product under evaluation has received. The main differences between the first study and this one consist of:

1. Besides Assisted and Automated (both provided by DTC Autonomus app), one more variation of Design Thinking Canvas was introduced to serve as our control group. It consists of the Offline, meaning that such agile teams will execute the methodology in its entirety through human activity.
2. The evaluation in Study 2 is centered on the products created from such methodological variations to analyze how they compare to each other.

In the next chapter, we present more general results, including a comparison between Study 1 and 2 statistical results, but in this section, we specifically want to evaluate the impact of methodological variations in the products they create while comparing the two experiments from this study. Thus, we present and discuss the results from Kruskal-Wallis statistical test regarding the all criteria presented in the research methodology chapter.

From game development experiment, we will consider the three games development by each team as they have individually executed a variation from the methodology. For its turn, from multimedia design teams, we will sample three apps from the total set, but considering at least one in each methodological variation. All data was collected through online questionnaire from June 19th 2017 until June 24th, 2017 for games' experiment and from June 16th 2017 until June 22nd 2017.

First, we will compare the results from game development and multimedia design contexts for the same criteria of the first Study, in order to check any variation between these two domains regarding the performance of each Design Thinking Canvas variation – Offiline, Assisted and Automated. Later, we will conduct separate analysis for game development and multimedia design products, but using only the new criteria introduced just for Study 2.

As hypothesis for this experiment, we say that there is no difference between the evaluation scores for Offline, Assisted and Automated products (games and apps). Again, to conduct all of our analysis we make use of IBM SPSS Statistics software, version 24 ("IBM SPSS Statistics", 2017). We formally state our hypothesis in terms of population distribution of evaluation scores among the following products groups from each DTC variation: Offline ($X_o$), Assisted ($X_{as}$), and Automated ($X_{at}$), for a $\alpha = 0.05$ as significance. Thus, we have the following null ($H_0$) and alternative hypothesis ($H_1$) for all the considered criteria in each analysis:

$H_0: F(X_o) = F(X_{as}) = F(X_{at})$

*vs.*

$H_1: \exists\ i,j: F(X_i) \neq F(X_j)\ (i \neq j;\ i,j = o, as, at)$

In the results presented in the following sections, the column for the grouping variable "DTCversion" is comprised of the values: *Offline*, *Automated* and *Assisted* to mark each methodological variation for Design Thinking Canvas applied for such products, as previously explained. To differentiate both experiments in the results, we will follow the naming convention as: "Study 2 – Games", for game development samples and "Study 2 – Apps", for multimedia design samples.

#### *5.2.4.1 Quantitative results: comparison of games and apps evaluations under main criteria*

We start off by showing the results of a comparison between the evaluation of game and apps considering only the criteria from Study 1, we consider this is the most important result from these quantitative results. The objective of this analysis is to uncover particularities from Study 2 results considering its much more expanded perspective of having three versions of Design Thinking Canvas being executed at the same time, which did not happen in the first study.

The first step from Kruskal-Wallis test is to check the results from means ranks comparison and the significance of such figures (see Table 28). We have bold highlighted the main results from this test, considering the adopted significance (.$\alpha$ = 0.05).

Table 28 – Comparison of Study 2 experiments: games and apps under Creativity, Viability, Suitability and Technical Complexity results.

| DTC version | | Kruskal-Wallis test results comparison | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Viability | | Creativity | | Suitability | | TechnicalComplexity | |
| | | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** |
| *Mean Ranks* | **Offline** | 52.35 | 32.79 | 57.07 | 31.43 | 58.03 | 29.93 | 42.25 | 30.95 |
| | **Assisted** | 54.29 | 27.76 | 55.76 | 32.57 | 47.37 | 32.14 | 50.16 | 21.14 |
| | **Automated** | 47.85 | 35.45 | 41.66 | 32.00 | 49.10 | 33.93 | 62.09 | 43.90 |
| *Chi-Square* | | .900 | 2.017 | 6.166 | .044 | 2.836 | .542 | 8.342 | 17.972 |
| *df* | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *Asymp. Sig.* | | .638 | .365 | .046 | .978 | .242 | .763 | .015 | .000 |
| *Exact Sig.* | | .641 | .370 | **.045** | .981 | .242 | .766 | **.014** | **.000** |
| *Point Probability* | | .000 | .006 | .000 | .002 | .000 | .000 | .000 | .000 |

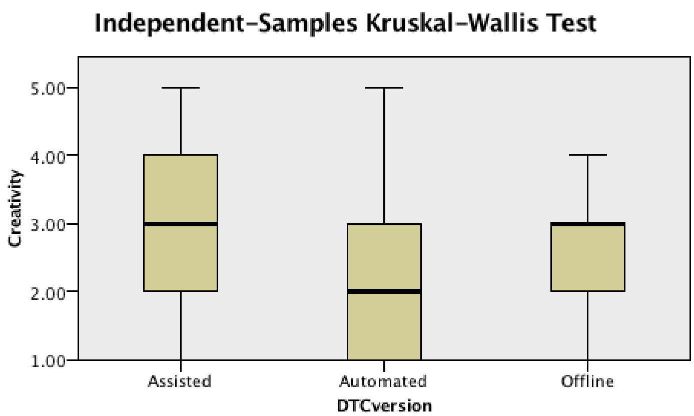
Study 2 Apps (N=34) | Study 2 Games (N=21)

Source: created by the author.

From such initial results, we can see that under Viability and Suitability dimensions both experiments performed equally with no statistical difference between them neither under any methodological variation. The strength of this finding is that the same behavior was found in two different experimental contexts, which means that Design Thinking Canvas, regardless of its variation, indeed deliver results that are market relevant for both market and user perspective.

For Creativity, we had already borderline results in favor of Assisted concepts in Study 1. Now, on Study 2 we can see that there are significantly different results among the three versions of Design Thinking Canvas in Apps' experiment (p-value .045), but still we cannot say which one performed better. In order to check which DTC version had better scores, some further analysis must be conducted, namely pairwise mean ranks comparisons (see Figure 43 e 44). With this analysis, it is possible to note that Offline and Assisted apps does not have statistically different results (.849 p-value). But we can indeed notice that Automated performed worse than both Assisted and Offline apps (.040 and 0.25 p-value, respectively), meaning that this methodological variation is not a good choice for generating creative apps.

Figure 43 – Box-plot comparisons for Creativity on Study 2's Apps experiment



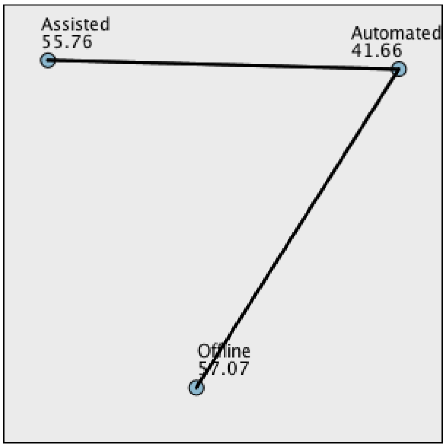

| | |
|---|---|
| Total N | 102 |
| Test Statistic | 6.166 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .046 |

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

Still in Creativity, no statistical difference happened on Games' experiment. We might account this difference to Apps' experiment due to the fact that game development teams had much more time to develop their products, which might have allowed all the teams to creatively equalize themselves over time. This leads us to hypothesize that for short time span projects it is important to consider the desired creativity level while deciding which DTC methodological variation to pick. Further experiments must be conducted to check these considerations in the future.

Figure 44 – Pairwise multiple mean ranks comparisons for Creativity on Study 2's Apps experiment

**Pairwise ...**




Each node shows the sample average rank of DTCversion.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Automated-Assisted | 14.103 | 6.882 | 2.049 | .040 | .121 |
| Automated-Offline | -15.412 | 6.882 | -2.239 | .025 | .075 |
| Assisted-Offline | -1.309 | 6.882 | -.190 | .849 | 1.000 |

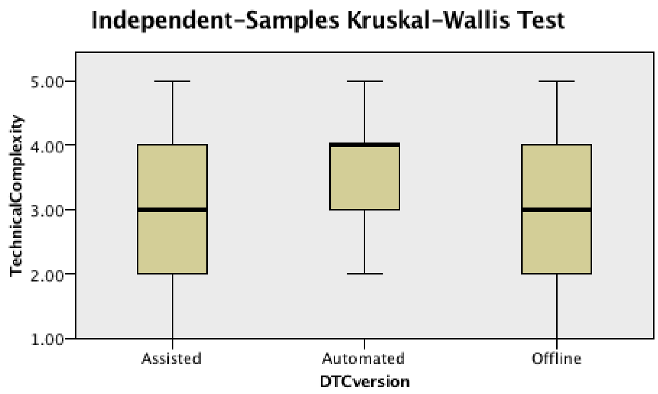
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

The most solid finding from Study 2's experiments is regarding Technical Complexity. The results for this dimension has shown significant statistical differences, meaning that some of DTC's variation has performed better than others in both experiments. As we did in Creativity, we must also conduct further analysis to reveal how each DTC variation compare to each other.

For Apps' experiment, what we can see from its bar-plot and pairwise comparisons is that Automated performed better than Offline products regarding Technical Complexity (p-value .004) (see Figure 45 and 46). We cannot state any statistical difference between the pairs: Automated-Assisted (although it approximates from .05 significance) and Assisted-Offline.

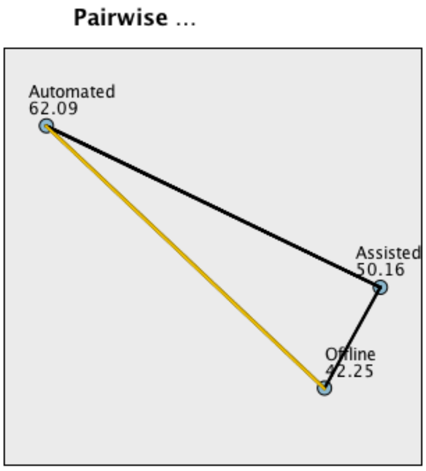
Figure 45 – Box-plot comparisons for Technical Complexity on Study 2's Apps experiment




| | |
|---|---|
| **Total N** | 102 |
| **Test Statistic** | 8.342 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .015 |

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

Figure 46 – Pairwise multiple mean ranks comparisons for Technical Complexity on Study 2's Apps experiment




Each node shows the sample average rank of DTCversion.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Offline-Assisted | 7.912 | 6.915 | 1.144 | .253 | .758 |
| Offline-Automated | 19.838 | 6.915 | 2.869 | .004 | .012 |
| Assisted-Automated | -11.926 | 6.915 | -1.725 | .085 | .254 |

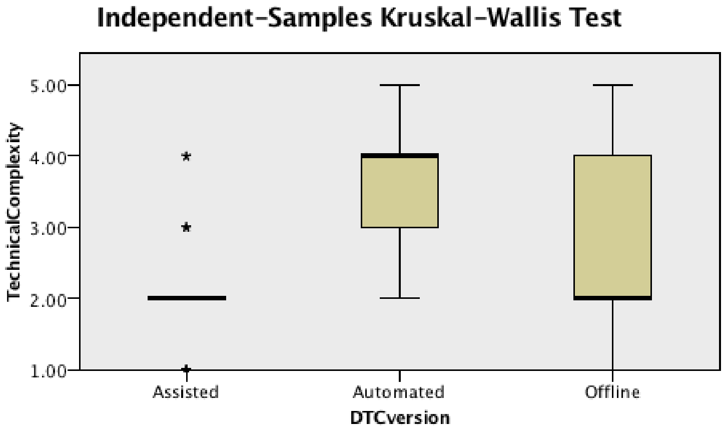
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

Still regarding Technical Complexity analysis, in Games' experiment we can state that the Automated game indeed performed better than Offline and Assisted ones (.000 and .016 p-value, respectively) (see Figures 47 and 48). At the same time, no significant difference was found between Assisted and Offline games.

Again, we can hypothesize that this much stronger difference in Technical Complexity than in Apps' experiment happened due to the latter shorter the time span, meaning that less technical evolution (and difference among agile teams) could be achieved in multimedia design setting. This is especially evident as we still found statistically borderline results favoring Automated from Automated-Assisted comparison. Further experiments with larger samples must be conducted to check these remarks. Anyway, these results show the strength that Design Thinking Canvas Autonomus app has in bringing higher levels of technical progression for agile setting.

Figure 47 – Box-plot comparisons for Technical Complexity on Study 2's Games experiment

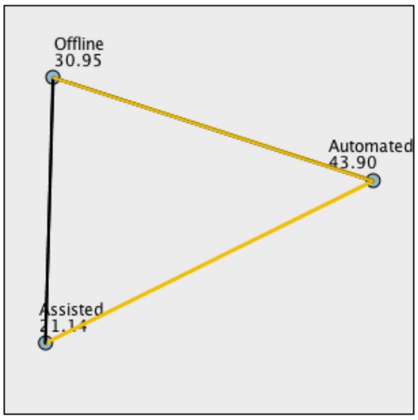



| | |
|---|---|
| **Total N** | 63 |
| **Test Statistic** | 17.972 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .000 |

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

Figure 48 – Pairwise multiple mean ranks comparisons for Technical Complexity on Study 2's Games experiment

**Pairwise ...**




Each node shows the sample average rank of DTCversion.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Assisted-Offline | -9.810 | 5.386 | -1.821 | .069 | .206 |
| Assisted-Automated | -22.762 | 5.386 | -4.226 | .000 | .000 |
| Offline-Automated | 12.952 | 5.386 | 2.405 | .016 | .049 |

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

As final remarks from all analysis in this section, we can say that these results statistically confirm, at least to some extent, some common-sense assumptions regarding design process: [1] human factors are important to creativity level of a project and; [2] computer assistance can indeed help design teams' productivity in terms of technical evolution. Thus, the balance between these two extremes above (consequently represented by DTC methodological extremes as well) must be sought in accordance to an agile team's pre-assessment of its strategic objectives regarding the product do be developed. In other words, agile projects intend to add value more quickly on costumer perspective, thus it is important to define beforehand what type of value is desired on case-by-case basis while applying or not Design Thinking Canvas´ technological assistance.

Below we present two tables to summarize all findings of this section after all pairwise comparisons between all Design Thinking Canvas variations for both experiments in this study (see tables 29 and 30).

Table 29 – Summarized results for DTC variations best scores in Apps' experiment.

| **Criteria** | Summarized results for Apps' experiment on each Design Thinking Canvas variation | | |
|---|---|---|---|
| | **Best DTC version** | **2nd place** | **Comments** |
| ***Creativity*** | Assisted and Offline | Automated | No statistical difference in Assisted-Offline pair. |
| ***Suitability*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Viability*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Technical complexity*** | Automated | Assisted and Offline | Automated had better scores than Offline and a borderline advantage to Assisted scores. No statistical difference was found in Assisted-Offline pair. |

Source: created by the author.

Table 30 – Summarized results for DTC variations best scores in Games' experiment.

| Criteria | Summarized results for Games' experiment on each Design Thinking Canvas variation | | | |
|---|---|---|---|---|
| | **Best DTC version** | **2nd place** | **3rd place** | **Comments** |
| ***Creativity*** | Automated, Assisted and Offline | | | No statistical difference between any pairwise comparison |
| ***Suitability*** | Automated, Assisted and Offline | | | No statistical difference between any pairwise comparison |
| ***Viability*** | Automated, Assisted and Offline | | | No statistical difference between any pairwise comparison |
| ***Technical complexity*** | Automated | Assisted | Offline | Automated had better scores than both Assisted and Offline. The pair Assisted-Offline comparison showed borderline advantage to Assisted. |

Source: created by the author.

#### *5.2.4.2 Quantitative results: comparison of games and apps evaluations under Study 2's criteria*

As we did in the previous section, we also conducted a similar analysis through Kruskal-Wallis statistical test, but this time only considering the new criteria introduced for Study 2. Thus, we set out to investigate how each version of Design Thinking Canvas methodology performs while creating products under these new criteria. Now, the interest is mostly on dimensions that measures how such products would result in its market and regarding Little Design Up-Front need for product flexibility. These have not been possible to investigate on the first study as it had only conceptual designs under consideration. Recalling the criteria for this second analysis, they are:

- Innovation: whether product novelty really results in the market it is inserted.
- Maturity: how close to an adequate level for public launch is the considered product.
- Minimum viable product: if the product under consideration can be considered an MVP or not.

- Flexibility: when facing new opportunities, how much open to changes and evolution across time is the product. It is considered under three sub-dimensions: concept, user interface and features.

All results from Kruskal-Wallis statistical test are presented on the tables below (see table 31 and 32). We will further discuss each analysis based on these figures throughout this section.

Table 31 – Comparison of Study 2 experiments: games and apps under market dimensions: Innovation, Maturity, Test Market Opportunity and MVP results.

| DTC version | | Kruskal-Wallis test results comparison | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Innovation** | | **Maturity** | | **Tests Market Opportunity** | | **MVP** | |
| | | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** |
| *Mean Ranks* | **Offline** | 60.09 | 32.48 | 59.78 | 32.95 | 60.18 | 33.93 | 59.16 | 35.79 |
| | **Assisted** | 53.38 | 31.31 | 50.44 | 25.36 | 48.09 | 29.12 | 49.76 | 27.90 |
| | **Automated** | 41.03 | 32.21 | 44.28 | 37.69 | 46.24 | 32.95 | 45.57 | 32.31 |
| *Chi-Square* | | 7.837 | .051 | 5.173 | 5.160 | 4.672 | .856 | 3.968 | 2.059 |
| *df* | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *Asymp. Sig.* | | .020 | .975 | .075 | .076 | .097 | .652 | .138 | .357 |
| *Exact Sig.* | | **.019** | .976 | .074 | .074 | .096 | .657 | .138 | .360 |
| *Point Probability* | | .000 | .001 | .000 | .000 | .000 | .000 | .000 | .001 |

Study 2 Apps (N=34) | Study Games (N=21)

Source: created by the author.

Table 32 – Comparison of Study 2 experiments: games and apps under LDUF criteria results.

| DTC version | | Kruskal-Wallis test results comparison | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Concept Flexibility** | | **Interface Flexibility** | | **Features Flexibility** | |
| | | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** | Study 2 **Apps** | Study 2 **Games** |
| *Mean Ranks* | **Offline** | 57.40 | 34.50 | 54.85 | 33.67 | 55.87 | 35.90 |
| | **Assisted** | 46.69 | 32.36 | 49.15 | 30.05 | 50.26 | 31.05 |
| | **Automated** | 50.41 | 29.14 | 50.50 | 32.29 | 48.37 | 29.05 |
| *Chi-Square* | | 2.791 | .974 | .814 | .446 | 1.432 | 1.673 |
| *df* | | 2 | 2 | 2 | 2 | 2 | 2 |
| *Asymp. Sig.* | | .248 | .615 | .666 | .800 | .489 | .433 |
| *Exact Sig.* | | .250 | .628 | .669 | .803 | .488 | .438 |
| *Point Probability* | | .000 | .000 | .000 | .002 | .000 | .000 |

Study 2 Apps (N=34) | Study Games (N=21)

Source: created by the author.

The first revealing finding was regarding all Little Design Up-Front-related product flexibility criteria (on concept, user interface and features level), as it was shown that all three versions of Design Thinking Canvas had no statistically difference on all of them in both experiments (see table 32). Two interpretations are possible. The first is that DTC methodology itself, regardless of its variation, is prepared or stimulate an evolutionary behavior on the products it creates. A second possible take on this finding is that all products from both experiments would need further development to evidence stronger differences among them.

Regarding the market-related dimensions, Minimum Viable Product pertinence and the ability to Test Market Opportunity criteria also did not show any statistical difference among DTC versions in both Apps and Games' experiments. Whether under Offline, Assisted or Automated variation, this finding reveals Design Thinking Canvas' strong orientation and preparation for market results. This is something easily verifiable given that methodology embeds several concepts (e.g. opportunity) and methods (e.g. value curve) that lead designers to consider such market-related dimensions when conceiving their products with it.

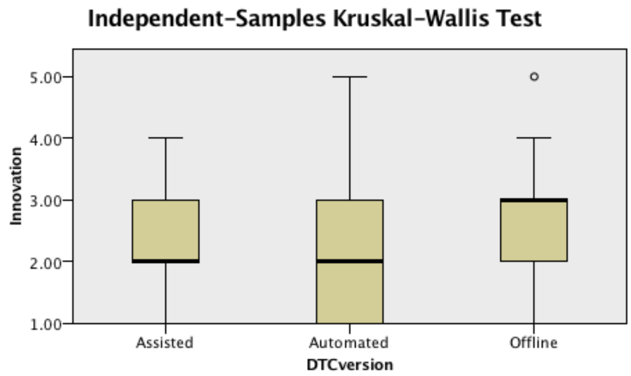
Another interesting finding comes from the results for the Maturity of the products, both experiments showed borderline figures (p-value of .074), meaning they were on the verge of revealing statistically different samples. A careful analysis of the mean ranks presents possibly opposite results for Automated variation of DTC: being the highest on

Games' and lowest on Apps' experiment. A possible explanation for such difference might reside in the fact that games' projects had much more development time, possibly meaning design teams had much more possibility to elevate maturity level of their products, which did not happen on apps' projects. This hypothesis needs further investigation (e.g. controlling time variations) or slightly larger samples for it to be verified.

The only criteria that indeed revealed statistically significant difference was Innovation but only in Apps' experiment (p-value of .019), meaning that at least one of DTC versions performed better than other. As we did in the previous section, further analysis is necessary to pinpoint which pair(s) had such discrepancy on their scores. Thus, we have to examine its box-plot representation and pairwise comparisons to check DTC versions' relative position to each other (see figure 49 and 50).

The analysis of Innovation pairwise comparison of the mean ranks reveals that Automated performed worse than both Assisted and Offline apps. At the same time, no statistical difference between Assisted and Offline could be found. The interpretation from such results is made easy when taken together with the findings for Creativity in the previous section (also for Apps' experiment), as this dimension also revealed exactly the same relative behavior of Innovation here. This fact reveals a strong relationship and importance of creativity to the innovation, also shows coherence between such findings. This same coherence can be found in Games' experiment as both Innovation and Creativity did not show statistical difference at the same time. Overall, it restates and quantifies the intimate connection between creativity and innovation concepts, as defined in chapter 2.

Figure 49 – Box-plot comparisons for Technical Complexity on Study 2's Apps experiment




| | |
|---|---|
| **Total N** | 102 |
| **Test Statistic** | 7.837 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .020 |

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

Figure 50 – Pairwise multiple mean ranks comparisons for Innovation on Study 2's Apps experiment

**Pairwise ...**


Each node shows the sample average rank of DTCversion.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Automated-Assisted | 12.353 | 6.907 | 1.788 | .074 | .221 |
| Automated-Offline | -19.059 | 6.907 | -2.759 | .006 | .017 |
| Assisted-Offline | -6.706 | 6.907 | -.971 | .332 | .995 |

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Source: Screenshot from IBM SPSS Statistics ("IBM SPSS Statistics", 2017)

We finalize this section with a summarization of the findings regarding all criteria considered in this section, as we did in the previous section (see table 33 and 34). It helps to clarify how each methodological variation of Design Thinking Canvas performed in relation to each other on all dimensions. Overall, we could not find many statistically significant differences among Offline, Assisted and Automated versions. Anyway, this summarized representation helps to easily recall Study 2's findings.

Table 33 – Summarized results for DTC variations best scores in Apps' experiment for Study 2's new criteria

| Criteria | Summarized results for Apps' experiment on each Design Thinking Canvas variation | | |
|---|---|---|---|
| | **Best performing DTC version** | **2nd place** | **Comments** |
| ***Innovation*** | Assisted and Offline | Automated | No statistical difference in Assisted-Offline pair comparison. |
| ***Maturity*** | Automated, Assisted and Offline | | No statistical difference, but a borderline result was found. |
| ***Tests Market Opportunity*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Minimum Viable Product*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Concept Flexibility*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Interface Flexibility*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |

Source: created by the author.

Table 34 – Summarized results for DTC variations best scores in Games' experiment for Study 2's new criteria

| Criteria | Summarized results for Games' experiment on each Design Thinking Canvas variation | | |
|---|---|---|---|
| | **Best performing DTC version** | **2nd place** | **Comments** |
| ***Innovation*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Maturity*** | Automated, Assisted and Offline | | No statistical difference, but a borderline result was found. |
| ***Tests Market Opportunity*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Minimum Viable Product*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Concept Flexibility*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Interface Flexibility*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |
| ***Features Flexibility*** | Automated, Assisted and Offline | | No statistical difference between any pairwise comparison |

Source: created by the author.

# 6 RESULTS AND DISCUSSION

In this chapter, we will discuss the final results from a unified analysis of the three experiments conducted by our research in its two main studies (concept design, game products and apps products), as thoroughly detailed in the previous chapter. The objective here is to expand each individual analysis and also contextualize them with information from the observations as well. This can provide further insights and evidences from our research. As scientific contribution, we finalize this chapter by presenting summarized description of some previous published works by the thesis' author that contributed to this research and helped to validate our its overall focus.

## *6.1 Comparing our three experimental results from Study 1 and Study 2*

We start off with the most important panorama that can be developed in our research, it consists of the simultaneous comparison among our three experiments under its common criteria (see table 35 and 36). It gives a complete perspective from the impact of such methodological variations in design process, since conceptual phases until product development. In order to provide a full picture of the results, we are limited to Study 1's criteria and number of samples, as in this study only four criteria were considered (Creativity, Suitability, Viability and Technical Complexity) and only two variations of Design Thinking Canvas were evaluated then (Assisted and Automated).

Regarding Suitability and Viability criteria, we could not find any statistical difference among any DTC variations in all three experiments. It means that Design Thinking Canvas, regardless of its variation, generates relevant solutions for the market (Viability) and adequate products for its users while solving their problems (Suitability). We explain that due to the fact that the methodology itself has several methods related to business concepts and also has a strong focus on user-centered design, which leads designers to have this balanced focus while applying Design Thinking Canvas.

Table 35 – Comparison of Study 1 and Study 2 results for DTC variations under Creativity and Suitability criteria

| DTC Version | | *Wilcoxon-Mann-Whitney* test results comparison | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Creativity** | | | **Suitability** | | |
| | | Study 1 (Concepts) | Study 2 (Apps) | Study 2 (Games) | Study 1 (Concepts) | Study 2 (Apps) | Study 2 (Games) |
| **Mean Ranks** | Assisted | **46.85** | **39.06** | 21.69 | 39.10 | 33.90 | 20.98 |
| | Automated | 38.15 | 29.94 | 21.31 | 45.90 | 35.10 | 22.02 |
| *Mann-Whitney U* | | 699.500 | 423.000 | 216.500 | 739.000 | 557.500 | 209.500 |
| *Wilcoxon W* | | 1602.500 | 1018.000 | 447.500 | 1642.000 | 1152.500 | 440.500 |
| *Z* | | -1.681 | -1.968 | -.104 | -1.327 | -.265 | -.288 |
| *Asymp. Sig. (2-tailed)* | | .093 | .049 | .917 | .184 | .791 | .774 |
| *Exact Sig. (2-tailed)* | | **.093** | **.049** | .925 | .188 | .798 | .790 |
| *Exact Sig. (1-tailed)* | | .046 | .025 | .463 | .094 | .399 | .395 |
| *Point Probability* | | .000 | .001 | .010 | .002 | .003 | .017 |

Study 1 (N=21) | Study 2 Apps (N=34) | Study 2 Games (N=21)

Source: created by the author.

Table 36 – Comparison of Study 1 and Study 2 results for DTC variations under Viability and Technical Complexity criteria

| DTC Version | | *Wilcoxon-Mann-Whitney* test results comparison | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Viability** | | | **TechnicalComplexity** | | |
| | | Study 1 (Concepts) | Study 2 (Apps) | Study 2 (Games) | Study 1 (Concepts) | Study 2 (Apps) | Study 2 (Games) |
| **Mean Ranks** | Assisted | 41.12 | 36.56 | 19.00 | 42.69 | 30.59 | 14.02 |
| | Automated | 43.88 | 32.44 | 24.00 | 42.31 | **38.41** | **28.98** |
| *Mann-Whitney U* | | 824.000 | 508.000 | 168.000 | 874.000 | 445.000 | 63.500 |
| *Wilcoxon W* | | 1727.000 | 1103.000 | 399.000 | 1777.000 | 1040.000 | 294.500 |
| *Z* | | -.539 | -.883 | -1.356 | -.075 | -1.697 | -4.112 |
| *Asymp. Sig. (2-tailed)* | | .590 | .377 | .175 | .941 | .090 | .000 |
| *Exact Sig. (2-tailed)* | | .601 | .379 | .178 | .947 | **.091** | **.000** |
| *Exact Sig. (1-tailed)* | | .301 | .190 | .089 | .473 | .046 | .000 |
| *Point Probability* | | .008 | .002 | .005 | .004 | .003 | .000 |

Study 1 (N=21) | Study 2 Apps (N=34) | Study 2 Games (N=21)

Source: created by the author.

On Creativity (see table 35), here we have similar results from the previous chapter, meaning that human intervention can indeed play a relevant part on it. In Study 1 and Study 2 Apps' experiments we have borderline (.093 p-value) and significant differences (.049 p-value) in favor of Assisted version of DTC, respectively. The same finding cannot be taken from Games' experiment, we attribute this to the fact that these projects had more time be developed and end up being more equalized in this sense. In other words, Automated projects, which are creatively worse at the outset, end up having more and more human intervention and influence on creative factors across time as long as the project gets. Further investigations should be made to validate these claims, but from our qualitative findings we could see that the Automated game project had several more iterations on its Game Design document than the other projects (see table 38), for example. It means that this team possibly had more time to creatively refine their "fixed concept" automatically generated by DTC Autonomus app.

From these two main comparison tables, the last important analysis to be made is about Technical Complexity factor (see table 36). In this dimension, we could find statistically significant difference in favor of Automated version of DTC in Games' experiments (.000 p-value). While in Apps' experiment, we can see that some statistical strength was lost compared to the previous chapter analysis, as we disregard Offline variation in this current comparison, but still leaving a borderline result (.091 p-value). Overall, these findings mean that automatically generated concepts allow agile teams to have more technical progression on their projects. We attribute this to the fact that these teams had more time to develop systematic tasks, like programming or interface development, which are only possible when you have at least some solid conceptual definition to build upon. This also justifies why it was not possible to verify such statistical advantage to Automated projects in Study 1 regarding Technical Complexity, as only conceptual designs were under a more shortsighted evaluation for a prospective feasibility then. With Design Thinking Canvas Autonomus' automatic concept generation feature, agile teams had a stable conceptual definition really quickly in matter of hours/minutes (compared to several days/weeks in Offline DTC projects), as we could perceive from our observations in both game development and multimedia design contexts. This is fairly applicable when agile teams work on established domains or faces a "designer-less" situation, where they have to accomplish more in terms of technical evolution as this is normally their main differential feature.

Another interesting comparison that can be made is regarding our findings for Suitability criterion, according to specialist designers' evaluation. This was the only dimension to point some statistically significant difference in Study 1, which happened in favor of Automated conceptual designs. As we can see, such statistical difference does not seem to have been transferred to product development on both experiments for Study 2 (see table 37). We hypothesize that a larger human factor influence during product development might have diminished the suitable advantage that Automated concepts had. Or, an alternative perspective on this is that also human factor might have positively increased suitability for Assisted products equalizing them with Automated ones. Further investigation controlling better these factors might be required to sustain such claims in the future.

Table 37 – Comparison of Study 1 (specialist designers sample) and Study 2 results for DTC variations under Suitability

| DTC Version | | *Wilcoxon-Mann-Whitney* test results comparison **Suitability** | | |
|---|---|---|---|---|
| | | Study 1 (Concepts) | Study 2 (Apps) | Study 2 (Games) |
| **Mean Ranks** | Assisted | 9.54 | 33.90 | 20.98 |
| | Automated | 15.46 | 35.10 | 22.02 |
| *Mann-Whitney U* | | 36.500 | 557.500 | 209.500 |
| *Wilcoxon W* | | 114.500 | 1152.500 | 440.500 |
| *Z* | | -2.167 | -.265 | -.288 |
| *Asymp. Sig. (2-tailed)* | | .030 | .791 | .774 |
| *Exact Sig. (2-tailed)* | | .037 | .798 | .790 |
| *Exact Sig. (1-tailed)* | | **.018** | .399 | .395 |
| *Point Probability* | | .003 | .003 | .017 |

Study 1 (N=6) | Study 2 Apps (N=34) | Study 2 Games (N=21)

Source: created by the author.

We can complement these overall criteria findings with a summarization from deliverables timeline from game development observation, as it can reveal some internal aspects regarding design process which is not possible to capture on those quantitative findings (see table 38). In practical terms, we can notice that Automated team had a much more easier schedule management regarding project scope until the final delivery deadline of 11th January 2017. Another interesting finding when crossing the quantitative results with the observation within games projects is that, regarding Little Design Up-Front need for flexible products, all of them showed equal capacity under statistical results from external evaluations, we could also notice such orientation towards product flexibility when observing this context but in different levels. Offline only reported some visual variations for the characters, while Assisted presented some possible improvement for user interface and

Automated presented a future vision to expand its game world with more levels, enemies and interactions.

Table 38 – Comparison of game design projects regarding their deliverables dates

| Deliverables | Automated team | Assisted team | Offline team |
|---|---|---|---|
| ***High level concept (canvas) definition*** | 23rd November 2016 | 12th December 2016 | 16th December 2016 |
| ***GDD first draft*** | 8th December 2016 | 19th December 2016 | 5th January 2017 |
| ***GDD iterations*** | 15th December 2016 and 11th January 2017 | 4th January 2017 and 11th January 2017 | 11th January 2017 |
| ***Visual assets first draft*** | 8th December 2016 | 11th January 2017 | 11th January 2017 |
| ***Visual assets iterations*** | 15th December 2016 and 11th January 2017 | - | - |

Source: created by the author.

Unfortunately, due to its very short time frame, such detailed deliverables comparison was not possible in multimedia design experiment. In this sense, we can only compare the deliveries by each individual team versus the expected due date of June 6th 2017 (see table 39). Anyway, these more general result also points to a more easier schedule management for Automated teams and harder for Offline teams.

Table 39 – Comparison of multimedia design projects regarding their delivery dates

| Deliverables | Automated teams | Assisted teams | Offline teams |
|---|---|---|---|
| ***Ahead of time*** | Team #3 (June 5th 2017) | | |
| ***On time*** | Team #4 | Team #2, Team #5 and Team #7 | Team #6 |
| ***Delayed*** | - | - | Team #8 and Team #1 (June 7th 2016) |

Source: created by the author.

## *6.2 Published works*

During the course of this PhD research, we published three peer-reviewed papers that enabled the author to refine and validate his research focus. We give each ones' titles and a summarized description of them:

- Title: A Theoretical Framework for Addressing Little Design Up-Front in Agile Projects Settings (FERNANDES; NEVES, 2016a): this work presented a literature review on agile context for design activity and also defined our theoretical stance in handling LDUF as research problem.
- Title: An ontology for conceptual design automation within agile projects (FERNANDES; NEVES, 2016b): this paper presented and discussed the ontological basis for what would become Design Thinking Canvas Antonomus app as computational tool to assist and automate design activity.
- Title: Design Thinking Canvas methodology: using canvas with cards to innovative artifact design (CALADO *et al.*, 2016): this last one is focused in describing Design Thinking Canvas methodology structure and also gives a glimpse of its overall applicability.

We are on the verge of publishing one more work on Computers in Human Behavior (Computers in Human Behavior, [s.d.]), which is a peer-reviewed indexed journal. The paper is provisionally entitled: "Comparing human versus computer generated designs: new possibilities for designer-computer relationship within agile projects". It has already received an appraisal from the journal's main editor, but it still under revision to decide about its publication. The scope of this paper is basically the discussion that has been brought to light under Study 1's experiment from this thesis, but with a stronger focus on designer's cognitive impact while having a computer to assist its practice.

# 7 CONCLUSION

Agile approach has the main characteristic of providing flexibility to product planning across time and close costumer collaboration by constantly iterating the product under development. This paradigm has been gaining momentum since 2001, when Agile Manifesto was launched to set the basis of what could be then a novel approach to product development. Since then, its methodologies and frameworks have been extensively investigated, adapted and used by a large number of organizations and not only by technology departments. Thus, agile has also been increasingly relevant to design activity as well, especially considering that agile teams are inherently multidisciplinary.

After considering his personal motivation, professional background as digital product manager and interest for such set of agile practices, the main author has delved into the literature regarding the insertion of design activity in such context of practice created by agile. His objective was to uncover possible research opportunities as this paradigm has a particular approach to problem-solving and product development, which clashes directly with classical waterfall paradigm, it is expected that this also brings some implications to design practice. The most relevant theme we found from several other literate reviews in such conjunction is called Little Design Up-Front, which stands as a principle by which design activity must be conducted in small portions, only to uncover sufficient progress to the project at a specific point in time.

Thus, our research has been focused on tooling design process with technological assistance in order to make agile teams more capable of addressing Little Design Up-Front. We did so by using a design thinking methodology, called Design Thinking Canvas, as our primary object of study. More specifically, we hypothesized that its mobile app, called Design Thinking Canvas Autonomus, would prove useful to this end. This software application has two main features: [1] by providing an extensive database of design-related information (e.g. Personas), it is capable of assisting designers in decision-making process to generate conceptual designs for their projects and [2] using this same database the app itself can automatically generate several conceptual designs, if designers want so.

In order to assess Design Thinking Canvas Autonomus capability to assist designers within agile projects, our research was divided in two big studies. Study 1 was focused on the evaluation Autonomus efficacy in providing relevant conceptual designs. This was the first step before considering a more practical experiment that would apply such technological tool. We conducted such evaluation inspired by Turing’s classical experiment to check whether evaluators could perceive such concepts as being generated by a computational machine or not. What we found was that, when compared to human intervened designs, automated designs would perform just as good as them in all considered criteria of: Creativity, Viability, Suitability and Feasibility. To conduct such analysis, we performed Wilcoxon-Mann-Whitney statistical test where we found mostly no statistically significant difference between assisted and automated designs. Actually, when considering only the evaluation from design specialists, the automated design concepts generated by Autonomus had positive statistical difference regarding Suitability. We attributed such finding to the exempt and conformity-oriented approach that computers normally have. From such results, we concluded that Design Thinking Canvas Autonomus would be as precise as a human manipulating the app itself and consequently viable to be applied in agile projects.

A design project has several steps after its conceptual definition which was the only focus in Study 1. Thus, after such relevant, albeit partial, conclusions from Study 1 and given the practical background of our research, we decided it would be necessary to explore such tool in real-world agile projects. Accordingly, a second study was conducted that was mostly interested in evaluating the resulting products to verify if the benefits and results obtained only in conceptual level in the first study would be confirmed in this real-world setting. In order to expand and possibly contrast the results from different domains, we setup two new separate experiments in this second study, one happening in a game development program and another one located at a multimedia design program. This time, we combined the methods of direct observation, while the products were being developed, and expert evaluation through questionnaire after all products completion. These two methods indeed proved useful for both experiments.

Through the analysis of all considered criteria, we can conclude that Design Thinking Canvas Autonomus is indeed helpful for agile projects, as several advantages were found from its application. We had a total of 34 data analysis instances considering all criteria and Design Thinking Canvas methodological variations in the three experiments we conducted. Most of them showed a statistical equivalence among all DTC's variations (Automated, Assisted and Offline). When taken without context, this information might lead to an uninformed conclusion that such variations are equivalent overall. But, it of uttermost importance to also consider the resources applied to implement such methodological variations (e.g. time, budget, team effort, etc.). When these factors are considered, we can firmly conclude that Automated and Assisted DTC's variation indeed provide the best results overall for design activity, meaning that Design Thinking Canvas Autonomus can have a positive impact for real-world agile projects. We consider this our main conclusion from our whole research.

At the same time, it is also important to caution uninformed applications from Design Thinking Canvas Autonomus app, especially under its variation that automatically generate design concepts (Automated). From all data, when taken only the 7 analysis instances that showed significant statistical difference (p-value < .05) (see table 40), we verify a really solid positive trend towards technical evolution from Automated products. We could indeed verify such capacity to evolve technically from the deliverables timeline showed in the previous chapter for both experiments, making these quantitative findings even more strong. But at the same time, it is important to acknowledge DTC's Automated variation weak performance under creative and innovation factors, meaning that a higher technical evolution advantage might come at the expense of a difficulty in novelty and market differentiation. So, the recommendation here is that agile teams must execute a strategical pre-assessment of its goals before deciding which variation of Design Thinking Canvas to pick, namely: between the extremes creative-innovative capacity and technical progression.

Table 40 – Sumarization of relative positions for each Design Thinking Canvas variation

| Criteria - Experiment | *Relative position to others Design Thinking Canvas variations* | | | Statistical Test |
|---|---|---|---|---|
| | **Automated** | **Assisted** | **Offline** | |
| ***Creativity - Apps*** | 2nd | 1st | 1st | Kruskal-Wallis |
| ***Technical complexity - Apps*** | 1st | 2nd | 2nd | Kruskal-Wallis |
| ***Technical complexity - Games*** | 1st | 2nd | 2nd | Kruskal-Wallis |
| ***Innovation - Apps*** | 2nd | 1st | 1st | Kruskal-Wallis |
| ***Creativity - Apps*** | 2nd | 1st | - | Wilcoxon-Mann-Whitney |
| ***Technical Complexity - Apps*** | 1st | 2nd | - | Wilcoxon-Mann-Whitney |
| ***Technical Complexity - Games*** | 1st | 2nd | - | Wilcoxon-Mann-Whitney |

Source: created by the author.

In summary, overall, we could not find statistical evidence to support any difference between computer automated, assisted and human generated designs. It means that Design Thinking Canvas Autonomus system was at least as efficient as human beings in most cases. This finding is especially relevant to our main objective of addressing Little Design Up-Front, as a clear objective for agile teams' developing product can be set up early on with minimal effort when using such tool, while still being relatively effective in the long run. It is worth mentioning that having clear goals is a factor that have significant impact on team performance (LU *et al.*, 2011). This contribution from Design Thinking Canvas Autonomus is especially relevant for startup-like teams as they usually suffer from lack of resources (e.g. limited financing or shortage of human resources).

In practical terms, for agile design projects Autonomus is an important tool to be considered, as the overall costs and efforts to develop design concepts by a non-human agent would be significantly lower. In this case, design teams can focus their attention or resources on more complex problems or tasks that machines cannot conduct within design projects. For instance, a higher number of sketches produced through critiques is already reported to enhance creativity in collaborative digital environments (KARAKAYA; DEMIRKAN, 2015), so it would be beneficial for design process to free up some time to focus on this type of activity.

López-Martinez and colleagues (LÓPEZ-MARTÍNEZ *et al.*, 2016) pointed out that one of the factors that prevents larger adoption from agile methodologies is sometimes the overstretch of teams' skills into being a "master of all trades" in order to create the desired product. Given all results presented, the adoption of Design Thinking Canvas Autonomus can provide, at least to some extent, good design capacity for unexperienced or even "designer-less" teams. This happens a lot in several domains, more than one would like to acknowledge, like Computer Science courses where students usually develop projects without any design guidance. So, besides the practical agile context, Autonomus can also help on design educational process for several fields other than design itself, generating a positive impact of the products created or the process adopted. In other words, creating the so much desired positive societal impact by Design Thinking, even in the absence of a human designer.

## 7.1 Limitations and future directions

We suggest further investigation especially regarding the application of such methodological variations for Design Thinking Canvas in commercial products launched to its final users. This would mean that much more user-centered metrics or criteria would be considered. Consequently, the strategy dimensions (Acquisition, Retention and Monetization) from the DTC methodology would play a much more important role than they did in our work, meaning that Minimum Viable Product evaluation by specialists, for example, would be contrasted with real analytics data from the products.

Another limitation is that, although we gave out best efforts into being as diverse as possible in our project contexts and had significant samples on them, due to the extent of experimental work and operational limitations, we only addressed two different domains and some representative products from them. We suggest that different domains (e.g. health, education, etc.) and that more products are explored in order to expand and contrast with our findings. Also, more experiments controlling time factors across domains should also be conducted, as some of our analysis revealed variations between domains, which we mostly attributed to project length variations as our field observations could not demonstrate elucidate other aspects than this.

Regarding Design Thinking Canvas Autonomus as a tool, further developments must be made to increase its database with more design-related data, maybe for other domains than mobile apps only, as it is focused nowadays. Also, considering Autonomus' weakness in creative-innovative capacity found in its automated concepts, this tool also might need an improvement in its algorithm to diminish such gap. Further work is necessary regarding these two issues.

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# APPENDIX A – GAMES EXPERIMENT QUESTIONNAIRE

## Questionário - Suporte tecnológico a metodologias de Design Thinking

O questionário a seguir faz parte da pesquisa de doutoramento, cujo objetivo é instrumentalizar por meio de ferramentas tecnológicas as etapas conceituais de metodologias do Design Thinking para projetos ágeis.

Para participar, deve-se acessar o material relacionado aos 3 jogos e avalia-los através do questionário em sua respectiva seção.

Tempo estimado: 5-10 minutos.

A sua participação é totalmente espontânea e de forma alguma será exposta individualmente. Os dados coletados serão mantidos em completo sigilo, sendo os resultados demonstrados apenas de forma geral.

* Required

1. **Nome:** *

2. **Email:** *

### Jogo 1

Questões relacionadas ao jogo 1, analise de acordo com conceito apresentado.

### Gameplay - Jogo 1


http://youtube.com/watch?v=A8wF41JnhOc

3. **Considerando o conceito e o gameplay do jogo acima, avalie os seguintes critérios.... ***
(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | ◯ | ◯ | ◯ | ◯ | ◯ |
| Criatividade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Viabilidade econômica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Complexidade técnica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Adequabilidade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Maturidade | ◯ | ◯ | ◯ | ◯ | ◯ |

4. **Considerando o lançamento do jogo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações... ***

(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do jogo é um produto mínimo viável (MVP) | | | | | |
| O jogo testa claramente uma oportunidade de mercado | | | | | |
| O conceito do jogo é capaz de absorver melhorias ao longo do tempo | | | | | |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | | | | | |
| As funcionalidades e gameplay do jogo são capazes de absorver melhorias ao longo do tempo | | | | | |

## Jogo 2

Questões relacionadas ao jogo 2, analise de acordo com conceito apresentado.

## Gameplay - Jogo 2


http://youtube.com/watch?v=V1ocz5PjEYI

5. **Considerando o conceito e o gameplay do jogo acima, avalie os seguintes critérios.... ***
(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | ◯ | ◯ | ◯ | ◯ | ◯ |
| Criatividade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Viabilidade econômica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Complexidade técnica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Adequabilidade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Maturidade | ◯ | ◯ | ◯ | ◯ | ◯ |

6. **Considerando o lançamento do jogo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações.... ***
(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do jogo é um produto mínimo viável (MVP) | ◯ | ◯ | ◯ | ◯ | ◯ |
| O jogo testa claramente uma oportunidade de mercado | ◯ | ◯ | ◯ | ◯ | ◯ |
| O conceito do jogo é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| As funcionalidades e gameplay do jogo são capazes de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |

## Jogo 3

Questões relacionadas ao jogo 3, analise de acordo com conceito apresentado.

## Gameplay - Jogo 3


http://youtube.com/watch?v=4iZbRtbVOdg

7. **Considerando o conceito e o gameplay do jogo acima, avalie os seguintes critérios.... ***
(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Criatividade | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Viabilidade econômica | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Complexidade técnica | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Adequabilidade | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Maturidade | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

8. **Considerando o lançamento do jogo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações....** *

(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):

*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do jogo é um produto mínimo viável (MVP) | ◯ | ◯ | ◯ | ◯ | ◯ |
| O jogo testa claramente uma oportunidade de mercado | ◯ | ◯ | ◯ | ◯ | ◯ |
| O conceito do jogo é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| As funcionalidades e gameplay do jogo são capazes de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |

9. **Sobre sua experiência em metodologias ágeis...** *

*Mark only one oval.*

◯ Conheço e pratico no dia a dia em todos os projetos (é parte dos processos da minha organização)

◯ Conheço, mas apliquei apenas em alguns projetos (domino o conceito, adapto ou aplico parcialmente)

◯ Conheço, mas não aplico (já li sobre o assunto)

◯ Não conheço (nunca li sobre o assunto)

# APPENDIX B – APPS EXPERIMENT QUESTIONNAIRE

## Questionário - Suporte tecnológico a metodologias de Design Thinking

O questionário a seguir faz parte da pesquisa de doutoramento, cujo objetivo é instrumentalizar por meio de ferramentas tecnológicas as etapas conceituais de metodologias do Design Thinking para projetos ágeis.

Para participar, deve-se acessar o material relacionado aos 3 aplicativos e avalia-los através do questionário em sua respectiva seção.

Tempo estimado: 10-15 minutos.

A sua participação é totalmente espontânea e de forma alguma será exposta individualmente. Os dados coletados serão mantidos em completo sigilo, sendo os resultados demonstrados apenas de forma geral.

* Required

1. **Nome:** *

2. **Email:** *

## Protótipo - App 1: https://xd.adobe.com/view/b5f92291-6316-430b-b229-9c8d8023dd55/

3. **Considerando o conceito e o protótipo do aplicativo acima, avalie os seguintes critérios....** *

(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | | | | | |
| Criatividade | | | | | |
| Viabilidade econômica | | | | | |
| Complexidade técnica | | | | | |
| Adequabilidade | | | | | |
| Maturidade | | | | | |

4. **Considerando o lançamento do aplicativo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações....** *

(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do app é um produto mínimo viável (MVP) | | | | | |
| O app testa claramente uma oportunidade de mercado | | | | | |
| O conceito do app é capaz de absorver melhorias ao longo do tempo | | | | | |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | | | | | |
| As funcionalidades do app são capazes de absorver melhorias ao longo do tempo | | | | | |

## Protótipo - App 2: https://xd.adobe.com/view/d45737bb-1076-4451-a8c4-f14477dd084f/

5. **Considerando o conceito e o protótipo do aplicativo acima, avalie os seguintes critérios....** *

(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | ◯ | ◯ | ◯ | ◯ | ◯ |
| Criatividade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Viabilidade econômica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Complexidade técnica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Adequabilidade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Maturidade | ◯ | ◯ | ◯ | ◯ | ◯ |

6. **Considerando o lançamento do aplicativo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações....** *

(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do app é um produto mínimo viável (MVP) | ◯ | ◯ | ◯ | ◯ | ◯ |
| O app testa claramente uma oportunidade de mercado | ◯ | ◯ | ◯ | ◯ | ◯ |
| O conceito do app é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| As funcionalidades do app são capazes de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |

**Protótipo - App 3:** https://xd.adobe.com/view/d8ff82e4-0f9d-46b4-88a7-56b7bf7d9f88/

7. **Considerando o conceito e o protótipo do aplicativo acima, avalie os seguintes critérios....** *

(Dê uma nota de 1 a 5, onde 1 significa completamente ausente e 5 significa completamente presente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Inovação | ◯ | ◯ | ◯ | ◯ | ◯ |
| Criatividade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Viabilidade econômica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Complexidade técnica | ◯ | ◯ | ◯ | ◯ | ◯ |
| Adequabilidade | ◯ | ◯ | ◯ | ◯ | ◯ |
| Maturidade | ◯ | ◯ | ◯ | ◯ | ◯ |

8. **Considerando o lançamento do aplicativo como um produto mínimo viável (MVP), qual o seu nível de concordância para as seguintes afirmações....** *

(Dê uma nota de 1 a 5, onde 1 significa discordo plenamente e 5 significa concordo plenamente):
*Mark only one oval per row.*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A versão atual do app é um produto mínimo viável (MVP) | ◯ | ◯ | ◯ | ◯ | ◯ |
| O app testa claramente uma oportunidade de mercado | ◯ | ◯ | ◯ | ◯ | ◯ |
| O conceito do app é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| A interface com o usuário apresentada é capaz de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |
| As funcionalidades do app são capazes de absorver melhorias ao longo do tempo | ◯ | ◯ | ◯ | ◯ | ◯ |

9. **Sobre sua experiência em metodologias ágeis...** *

*Mark only one oval.*

- ◯ Conheço e pratico no dia a dia em todos os projetos (é parte dos processos da minha organização)
- ◯ Conheço, mas apliquei apenas em alguns projetos (domino o conceito, adapto ou aplico parcialmente)
- ◯ Conheço, mas não aplico (já li sobre o assunto)
- ◯ Não conheço (nunca li sobre o assunto)

# APPENDIX C – APPS EXPERIMENT DATA

| Evaluator | DTCversion | Innovation | Creativity | Viability | TechnicalComplexity | Suitability | Maturity | MVP | TestsMarketOpportunity | ConceptFlex | InterfaceFlex | FeaturesFlex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Offline | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 5 | 5 |
| 2 | Offline | 3 | 3 | 4 | 2 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 3 | Offline | 3 | 3 | 4 | 2 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 4 | Offline | 2 | 2 | 1 | 1 | 3 | 2 | 5 | 1 | 5 | 5 | 5 |
| 5 | Offline | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 5 |
| 6 | Offline | 3 | 3 | 4 | 3 | 4 | 4 | 2 | 5 | 5 | 4 | 4 |
| 7 | Offline | 4 | 3 | 2 | 2 | 5 | 4 | 3 | 5 | 5 | 5 | 5 |
| 8 | Offline | 3 | 3 | 4 | 2 | 3 | 4 | 3 | 5 | 5 | 5 | 4 |
| 9 | Offline | 3 | 3 | 4 | 3 | 4 | 2 | 5 | 4 | 5 | 5 | 5 |
| 10 | Offline | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 2 | 4 | 4 | 4 |
| 11 | Offline | 3 | 3 | 4 | 4 | 2 | 3 | 2 | 4 | 5 | 5 | 5 |
| 12 | Offline | 4 | 2 | 3 | 1 | 4 | 4 | 5 | 3 | 5 | 5 | 5 |
| 13 | Offline | 3 | 4 | 5 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 |
| 14 | Offline | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| 15 | Offline | 4 | 3 | 5 | 4 | 4 | 2 | 5 | 5 | 5 | 5 | 5 |
| 16 | Offline | 2 | 2 | 2 | 4 | 4 | 2 | 4 | 3 | 4 | 2 | 4 |
| 17 | Offline | 3 | 4 | 4 | 4 | 5 | 4 | 2 | 5 | 5 | 5 | 5 |
| 18 | Offline | 1 | 1 | 1 | 2 | 2 | 2 | 5 | 1 | 3 | 5 | 5 |
| 19 | Offline | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 5 | 3 | 4 |
| 20 | Offline | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 4 |
| 21 | Offline | 2 | 3 | 3 | 3 | 4 | 5 | 5 | 3 | 4 | 4 | 4 |
| 22 | Offline | 1 | 2 | 2 | 3 | 3 | 2 | 4 | 2 | 3 | 4 | 3 |
| 23 | Offline | 3 | 2 | 5 | 2 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| 24 | Offline | 2 | 3 | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| 25 | Offline | 2 | 2 | 4 | 3 | 4 | 3 | 2 | 2 | 5 | 1 | 5 |
| 26 | Offline | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 4 | 5 | 5 | 5 |
| 27 | Offline | 2 | 3 | 3 | 2 | 3 | 4 | 4 | 3 | 4 | 4 | 4 |
| 28 | Offline | 2 | 3 | 3 | 5 | 2 | 4 | 4 | 5 | 5 | 5 | 5 |
| 29 | Offline | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| 30 | Offline | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 3 | 5 | 5 | 5 |
| 31 | Offline | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 4 | 4 | 4 |
| 32 | Offline | 2 | 2 | 4 | 3 | 3 | 4 | 1 | 2 | 3 | 3 | 3 |
| 33 | Offline | 3 | 3 | 4 | 4 | 5 | 4 | 5 | 5 | 4 | 4 | 4 |
| 34 | Offline | 2 | 2 | 2 | 5 | 3 | 1 | 2 | 3 | 5 | 5 | 5 |
| 1 | Automated | 3 | 5 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 5 |
| 2 | Automated | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 3 | Automated | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 4 | Automated | 1 | 1 | 2 | 2 | 2 | 2 | 4 | 2 | 4 | 4 | 4 |
| 5 | Automated | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 |
| 6 | Automated | 3 | 3 | 3 | 5 | 4 | 5 | 2 | 4 | 5 | 3 | 4 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Automated | 1 | 2 | 2 | 3 | 3 | 2 | 3 | 2 | 5 | 5 | 5 |
| 8 | Automated | 2 | 2 | 2 | 3 | 3 | 2 | 4 | 3 | 5 | 3 | 4 |
| 9 | Automated | 2 | 2 | 3 | 4 | 4 | 2 | 4 | 3 | 5 | 5 | 5 |
| 10 | Automated | 2 | 2 | 3 | 3 | 3 | 3 | 1 | 1 | 3 | 3 | 3 |
| 11 | Automated | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 5 | 5 | 5 |
| 12 | Automated | 1 | 1 | 3 | 3 | 2 | 2 | 3 | 1 | 2 | 5 | 5 |
| 13 | Automated | 2 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 14 | Automated | 1 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 4 | 4 |
| 15 | Automated | 3 | 3 | 5 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| 16 | Automated | 1 | 2 | 1 | 5 | 2 | 2 | 3 | 2 | 4 | 4 | 4 |
| 17 | Automated | 2 | 3 | 5 | 4 | 4 | 3 | 4 | 2 | 5 | 5 | 4 |
| 18 | Automated | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 5 | 5 | 5 | 5 |
| 19 | Automated | 2 | 2 | 4 | 4 | 3 | 3 | 4 | 3 | 5 | 5 | 5 |
| 20 | Automated | 3 | 3 | 3 | 4 | 3 | 2 | 2 | 3 | 4 | 4 | 4 |
| 21 | Automated | 1 | 1 | 2 | 3 | 3 | 2 | 4 | 1 | 2 | 2 | 2 |
| 22 | Automated | 1 | 1 | 3 | 3 | 3 | 1 | 1 | 2 | 4 | 3 | 4 |
| 23 | Automated | 2 | 2 | 5 | 4 | 4 | 4 | 3 | 5 | 5 | 4 | 5 |
| 24 | Automated | 3 | 4 | 4 | 2 | 4 | 4 | 3 | 3 | 4 | 4 | 4 |
| 25 | Automated | 1 | 1 | 2 | 4 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| 26 | Automated | 1 | 1 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 4 |
| 27 | Automated | 2 | 2 | 4 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| 28 | Automated | 1 | 1 | 1 | 4 | 4 | 3 | 1 | 5 | 5 | 5 | 5 |
| 29 | Automated | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| 30 | Automated | 3 | 4 | 3 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 31 | Automated | 1 | 1 | 3 | 2 | 3 | 2 | 3 | 2 | 4 | 5 | 3 |
| 32 | Automated | 2 | 2 | 2 | 5 | 3 | 3 | 3 | 4 | 5 | 5 | 5 |
| 33 | Automated | 3 | 3 | 5 | 5 | 4 | 3 | 5 | 5 | 5 | 5 | 5 |
| 34 | Automated | 1 | 1 | 1 | 5 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |
| 1 | Assisted | 3 | 3 | 5 | 3 | 3 | 3 | 5 | 3 | 5 | 5 | 5 |
| 2 | Assisted | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 5 |
| 3 | Assisted | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 5 |
| 4 | Assisted | 1 | 2 | 1 | 2 | 2 | 2 | 4 | 1 | 5 | 5 | 5 |
| 5 | Assisted | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 5 |
| 6 | Assisted | 2 | 3 | 3 | 5 | 3 | 3 | 5 | 3 | 5 | 5 | 5 |
| 7 | Assisted | 2 | 2 | 1 | 4 | 2 | 2 | 3 | 1 | 5 | 5 | 5 |
| 8 | Assiste | 3 | 3 | 4 | 3 | 3 | 2 | 4 | 4 | 5 | 5 | 5 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | | | | | | | | | | | |
| 9 | Assisted | 2 | 2 | 3 | 3 | 3 | 2 | 5 | 5 | 5 | 5 | 5 |
| 10 | Assisted | 2 | 2 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 3 |
| 11 | Assisted | 2 | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 5 | 5 | 5 |
| 12 | Assisted | 2 | 2 | 4 | 3 | 2 | 2 | 2 | 2 | 5 | 3 | 5 |
| 13 | Assisted | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 14 | Assisted | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 4 | 4 | 4 |
| 15 | Assisted | 4 | 3 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| 16 | Assisted | 2 | 2 | 3 | 3 | 4 | 3 | 2 | 4 | 2 | 3 | 3 |
| 17 | Assisted | 4 | 5 | 5 | 3 | 4 | 4 | 5 | 5 | 5 | 5 | 4 |
| 18 | Assisted | 2 | 2 | 2 | 1 | 3 | 2 | 5 | 2 | 3 | 5 | 5 |
| 19 | Assisted | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 20 | Assisted | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 3 | 3 |
| 21 | Assisted | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| 22 | Assisted | 1 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 4 | 4 | 4 |
| 23 | Assisted | 3 | 4 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 24 | Assisted | 2 | 3 | 3 | 2 | 3 | 3 | 4 | 3 | 3 | 3 | 4 |
| 25 | Assisted | 2 | 4 | 5 | 3 | 4 | 3 | 1 | 3 | 4 | 4 | 4 |
| 26 | Assisted | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 2 | 4 | 4 | 4 |
| 27 | Assisted | 2 | 3 | 4 | 3 | 4 | 3 | 2 | 3 | 4 | 4 | 4 |
| 28 | Assisted | 3 | 4 | 2 | 5 | 4 | 4 | 3 | 5 | 3 | 4 | 5 |
| 29 | Assisted | 3 | 3 | 4 | 5 | 4 | 4 | 4 | 3 | 5 | 5 | 5 |
| 30 | Assisted | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 5 |
| 31 | Assisted | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 1 | 4 | 4 | 3 |
| 32 | Assisted | 1 | 2 | 3 | 3 | 4 | 3 | 4 | 3 | 2 | 2 | 3 |
| 33 | Assisted | 3 | 3 | 5 | 5 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 34 | Assisted | 3 | 3 | 2 | 4 | 2 | 1 | 1 | 1 | 3 | 3 | 3 |

# APPENDIX D – GAMES EXPERIMENT DATA

| Evaluator | DTCversion | Innovation | Creativity | Viability | TechnicalComplexity | Suitability | Maturity | MVP | TestsMarketOpportunity | ConceptFlex | InterfaceFlex | FeaturesFlex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Assisted | 2 | 2 | 2 | 2 | 4 | 2 | 3 | 4 | 4 | 4 | 4 |
| 2 | Assisted | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | Assisted | 3 | 3 | 3 | 2 | 4 | 3 | 2 | 2 | 3 | 3 | 3 |
| 4 | Assisted | 2 | 2 | 2 | 3 | 4 | 5 | 4 | 4 | 4 | 3 | 3 |
| 5 | Assisted | 3 | 4 | 3 | 2 | 5 | 4 | 3 | 4 | 2 | 4 | 3 |
| 6 | Assisted | 3 | 4 | 3 | 3 | 4 | 1 | 1 | 2 | 3 | 4 | 5 |
| 7 | Assisted | 2 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 8 | Assisted | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 4 |
| 9 | Assisted | 2 | 3 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 3 | 4 |
| 10 | Assisted | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 3 |
| 11 | Assisted | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 3 | 2 |
| 12 | Assisted | 1 | 2 | 3 | 4 | 3 | 2 | 2 | 3 | 5 | 5 | 4 |
| 13 | Assisted | 1 | 1 | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 3 | 2 |
| 14 | Assisted | 3 | 4 | 2 | 2 | 3 | 4 | 5 | 3 | 4 | 4 | 4 |
| 15 | Assisted | 3 | 3 | 4 | 2 | 4 | 2 | 5 | 4 | 5 | 5 | 5 |
| 16 | Assisted | 4 | 4 | 4 | 2 | 3 | 2 | 5 | 5 | 5 | 5 | 5 |
| 17 | Assisted | 3 | 3 | 5 | 2 | 4 | 3 | 2 | 4 | 5 | 5 | 5 |
| 18 | Assisted | 2 | 4 | 1 | 1 | 2 | 2 | 5 | 2 | 4 | 4 | 4 |
| 19 | Assisted | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 5 | 5 |
| 20 | Assisted | 1 | 2 | 4 | 2 | 2 | 2 | 4 | 2 | 5 | 2 | 5 |
| 1 | Offline | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | Offline | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 3 | Offline | 1 | 2 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 | 2 |
| 4 | Offline | 2 | 2 | 2 | 1 | 3 | 3 | 4 | 4 | 4 | 2 | 3 |
| 5 | Offline | 2 | 1 | 2 | 4 | 1 | 2 | 2 | 1 | 2 | 3 | 1 |
| 6 | Offline | 3 | 3 | 4 | 2 | 3 | 2 | 3 | 3 | 4 | 4 | 4 |
| 7 | Offline | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 5 |
| 8 | Offline | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | 4 | 4 |
| 9 | Offline | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 3 | 3 |
| 10 | Offline | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| 11 | Offline | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| 12 | Offline | 1 | 3 | 4 | 2 | 5 | 4 | 5 | 4 | 5 | 3 | 5 |
| 13 | Offline | 1 | 2 | 3 | 2 | 2 | 2 | 4 | 3 | 4 | 5 | 3 |
| 14 | Offline | 4 | 5 | 4 | 4 | 3 | 5 | 5 | 4 | 5 | 5 | 5 |
| 15 | Offline | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 |
| 16 | Offline | 2 | 2 | 4 | 2 | 3 | 3 | 5 | 3 | 4 | 5 | 5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | Offline | 2 | 2 | 5 | 2 | 3 | 2 | 4 | 4 | 5 | 4 | 5 |
| 18 | Offline | 2 | 3 | 3 | 3 | 3 | 3 | 5 | 2 | 2 | 4 | 5 |
| 19 | Offline | 2 | 2 | 2 | 2 | 2 | 3 | 4 | 3 | 5 | 5 | 5 |
| 20 | Offline | 3 | 2 | 1 | 3 | 2 | 2 | 4 | 1 | 3 | 5 | 5 |
| 1 | Automated | 2 | 2 | 2 | 3 | 4 | 3 | 2 | 2 | 3 | 3 | 3 |
| 2 | Automated | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | Automated | 2 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 4 | Automated | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 5 | Automated | 1 | 1 | 2 | 4 | 4 | 3 | 3 | 2 | 3 | 2 | 4 |
| 6 | Automated | 1 | 1 | 3 | 3 | 2 | 2 | 2 | 1 | 3 | 5 | 3 |
| 7 | Automated | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 5 | 5 |
| 8 | Automated | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 3 | 4 | 5 |
| 9 | Automated | 2 | 2 | 3 | 4 | 2 | 2 | 3 | 2 | 2 | 2 | 3 |
| 10 | Automated | 1 | 2 | 4 | 4 | 2 | 3 | 1 | 3 | 4 | 4 | 4 |
| 11 | Automated | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 2 |
| 12 | Automated | 3 | 3 | 5 | 4 | 3 | 4 | 5 | 4 | 3 | 5 | 2 |
| 13 | Automated | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 |
| 14 | Automated | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 |
| 15 | Automated | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 16 | Automated | 2 | 2 | 3 | 4 | 3 | 3 | 3 | 2 | 4 | 4 | 2 |
| 17 | Automated | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 18 | Automated | 1 | 5 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 5 |
| 19 | Automated | 3 | 3 | 2 | 4 | 3 | 3 | 4 | 3 | 5 | 5 | 5 |
| 20 | Automated | 1 | 1 | 5 | 2 | 1 | 1 | 4 | 4 | 1 | 1 | 2 |
| 21 | Assisted | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| 21 | Offline | 2 | 3 | 3 | 2 | 3 | 1 | 2 | 3 | 5 | 4 | 4 |
| 21 | Automated | 1 | 2 | 1 | 3 | 1 | 1 | 4 | 1 | 3 | 1 | 1 |

# APPENDIX E – DESIGN CONCEPTS EXPERIMENT DATA

| Evaluator | Specialist | Project | Human | Creativity |
|---|---|---|---|---|
| 7 | 0 | 1 | 1 | 5 |
| 8 | 0 | 1 | 1 | 2 |
| 9 | 0 | 1 | 1 | 3 |
| 10 | 0 | 1 | 1 | 2 |
| 11 | 0 | 1 | 1 | 2 |
| 12 | 0 | 1 | 1 | 4 |
| 13 | 0 | 1 | 1 | 5 |
| 14 | 0 | 1 | 1 | 2 |
| 15 | 0 | 1 | 1 | 2 |
| 16 | 0 | 1 | 1 | 4 |
| 17 | 0 | 1 | 1 | 2 |
| 18 | 0 | 1 | 1 | 3 |
| 19 | 0 | 1 | 1 | 2 |
| 20 | 0 | 1 | 1 | 3 |
| 21 | 0 | 1 | 1 | 5 |
| 7 | 0 | 2 | 1 | 3 |
| 8 | 0 | 2 | 1 | 2 |
| 9 | 0 | 2 | 1 | 4 |
| 10 | 0 | 2 | 1 | 4 |
| 11 | 0 | 2 | 1 | 3 |
| 12 | 0 | 2 | 1 | 3 |
| 13 | 0 | 2 | 1 | 5 |
| 14 | 0 | 2 | 1 | 2 |
| 15 | 0 | 2 | 1 | 2 |
| 16 | 0 | 2 | 1 | 3 |
| 17 | 0 | 2 | 1 | 1 |
| 18 | 0 | 2 | 1 | 3 |
| 19 | 0 | 2 | 1 | 4 |
| 20 | 0 | 2 | 1 | 5 |
| 21 | 0 | 2 | 1 | 3 |
| 7 | 0 | 3 | 0 | 2 |
| 8 | 0 | 3 | 0 | 2 |
| 9 | 0 | 3 | 0 | 4 |
| 10 | 0 | 3 | 0 | 2 |
| 11 | 0 | 3 | 0 | 2 |
| 12 | 0 | 3 | 0 | 2 |
| 13 | 0 | 3 | 0 | 4 |
| 14 | 0 | 3 | 0 | 1 |
| 15 | 0 | 3 | 0 | 1 |
| 16 | 0 | 3 | 0 | 1 |
| 17 | 0 | 3 | 0 | 1 |
| 18 | 0 | 3 | 0 | 2 |

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| 19 | 0 | 3 | 0 | 1 |
| 20 | 0 | 3 | 0 | 1 |
| 21 | 0 | 3 | 0 | 3 |
| 7 | 0 | 4 | 0 | 3 |
| 8 | 0 | 4 | 0 | 3 |
| 9 | 0 | 4 | 0 | 3 |
| 10 | 0 | 4 | 0 | 3 |
| 11 | 0 | 4 | 0 | 4 |
| 12 | 0 | 4 | 0 | 2 |
| 13 | 0 | 4 | 0 | 5 |
| 14 | 0 | 4 | 0 | 4 |
| 15 | 0 | 4 | 0 | 1 |
| 16 | 0 | 4 | 0 | 4 |
| 17 | 0 | 4 | 0 | 1 |
| 18 | 0 | 4 | 0 | 3 |
| 19 | 0 | 4 | 0 | 1 |
| 20 | 0 | 4 | 0 | 3 |
| 21 | 0 | 4 | 0 | 4 |
| 1 | 1 | 1 | 1 | 2 |
| 2 | 1 | 1 | 1 | 3 |
| 3 | 1 | 1 | 1 | 2 |
| 4 | 1 | 1 | 1 | 4 |
| 5 | 1 | 1 | 1 | 3 |
| 6 | 1 | 1 | 1 | 2 |
| 1 | 1 | 2 | 1 | 4 |
| 2 | 1 | 2 | 1 | 3 |
| 3 | 1 | 2 | 1 | 2 |
| 4 | 1 | 2 | 1 | 2 |
| 5 | 1 | 2 | 1 | 2 |
| 6 | 1 | 2 | 1 | 2 |
| 1 | 1 | 3 | 0 | 2 |
| 2 | 1 | 3 | 0 | 1 |
| 3 | 1 | 3 | 0 | 1 |
| 4 | 1 | 3 | 0 | 1 |
| 5 | 1 | 3 | 0 | 3 |
| 6 | 1 | 3 | 0 | 3 |
| 1 | 1 | 4 | 0 | 5 |
| 2 | 1 | 4 | 0 | 4 |
| 3 | 1 | 4 | 0 | 5 |
| 4 | 1 | 4 | 0 | 1 |
| 5 | 1 | 4 | 0 | 3 |
| 6 | 1 | 4 | 0 | 3 |

| Evaluator | Specialist | Project | Human | FEASIBILITY |
|---|---|---|---|---|
| 7 | 0 | 1 | 1 | 3 |
| 8 | 0 | 1 | 1 | 3 |

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| 9 | 0 | 1 | 1 | 5 |
| 10 | 0 | 1 | 1 | 3 |
| 11 | 0 | 1 | 1 | 4 |
| 12 | 0 | 1 | 1 | 2 |
| 13 | 0 | 1 | 1 | 3 |
| 14 | 0 | 1 | 1 | 2 |
| 15 | 0 | 1 | 1 | 4 |
| 16 | 0 | 1 | 1 | 5 |
| 17 | 0 | 1 | 1 | 4 |
| 18 | 0 | 1 | 1 | 5 |
| 19 | 0 | 1 | 1 | 5 |
| 20 | 0 | 1 | 1 | 5 |
| 21 | 0 | 1 | 1 | 4 |
| 7 | 0 | 2 | 1 | 4 |
| 8 | 0 | 2 | 1 | 2 |
| 9 | 0 | 2 | 1 | 4 |
| 10 | 0 | 2 | 1 | 4 |
| 11 | 0 | 2 | 1 | 4 |
| 12 | 0 | 2 | 1 | 2 |
| 13 | 0 | 2 | 1 | 3 |
| 14 | 0 | 2 | 1 | 4 |
| 15 | 0 | 2 | 1 | 5 |
| 16 | 0 | 2 | 1 | 3 |
| 17 | 0 | 2 | 1 | 5 |
| 18 | 0 | 2 | 1 | 5 |
| 19 | 0 | 2 | 1 | 5 |
| 20 | 0 | 2 | 1 | 4 |
| 21 | 0 | 2 | 1 | 3 |
| 7 | 0 | 3 | 0 | 4 |
| 8 | 0 | 3 | 0 | 4 |
| 9 | 0 | 3 | 0 | 3 |
| 10 | 0 | 3 | 0 | 3 |
| 11 | 0 | 3 | 0 | 2 |
| 12 | 0 | 3 | 0 | 2 |
| 13 | 0 | 3 | 0 | 4 |
| 14 | 0 | 3 | 0 | 1 |
| 15 | 0 | 3 | 0 | 4 |
| 16 | 0 | 3 | 0 | 4 |
| 17 | 0 | 3 | 0 | 3 |
| 18 | 0 | 3 | 0 | 5 |
| 19 | 0 | 3 | 0 | 5 |
| 20 | 0 | 3 | 0 | 5 |
| 21 | 0 | 3 | 0 | 4 |
| 7 | 0 | 4 | 0 | 3 |
| 8 | 0 | 4 | 0 | 2 |
| 9 | 0 | 4 | 0 | 4 |

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|---|---|---|---|---|
| 10 | 0 | 4 | 0 | 5 |
| 11 | 0 | 4 | 0 | 4 |
| 12 | 0 | 4 | 0 | 2 |
| 13 | 0 | 4 | 0 | 4 |
| 14 | 0 | 4 | 0 | 3 |
| 15 | 0 | 4 | 0 | 4 |
| 16 | 0 | 4 | 0 | 5 |
| 17 | 0 | 4 | 0 | 4 |
| 18 | 0 | 4 | 0 | 5 |
| 19 | 0 | 4 | 0 | 5 |
| 20 | 0 | 4 | 0 | 4 |
| 21 | 0 | 4 | 0 | 4 |
| 1 | 1 | 1 | 1 | 4 |
| 2 | 1 | 1 | 1 | 5 |
| 3 | 1 | 1 | 1 | 4 |
| 4 | 1 | 1 | 1 | 4 |
| 5 | 1 | 1 | 1 | 2 |
| 6 | 1 | 1 | 1 | 4 |
| 1 | 1 | 2 | 1 | 2 |
| 2 | 1 | 2 | 1 | 2 |
| 3 | 1 | 2 | 1 | 2 |
| 4 | 1 | 2 | 1 | 5 |
| 5 | 1 | 2 | 1 | 4 |
| 6 | 1 | 2 | 1 | 4 |
| 1 | 1 | 3 | 0 | 3 |
| 2 | 1 | 3 | 0 | 2 |
| 3 | 1 | 3 | 0 | 5 |
| 4 | 1 | 3 | 0 | 5 |
| 5 | 1 | 3 | 0 | 5 |
| 6 | 1 | 3 | 0 | 4 |
| 1 | 1 | 4 | 0 | 2 |
| 2 | 1 | 4 | 0 | 3 |
| 3 | 1 | 4 | 0 | 4 |
| 4 | 1 | 4 | 0 | 5 |
| 5 | 1 | 4 | 0 | 3 |
| 6 | 1 | 4 | 0 | 3 |

| Evaluator | Specialist | Project | Human | SUITABILITY |
|---|---|---|---|---|
| 7 | 0 | 1 | 1 | 3 |
| 8 | 0 | 1 | 1 | 2 |
| 9 | 0 | 1 | 1 | 4 |
| 10 | 0 | 1 | 1 | 3 |
| 11 | 0 | 1 | 1 | 2 |
| 12 | 0 | 1 | 1 | 3 |
| 13 | 0 | 1 | 1 | 5 |

| | | | | |
|---|---|---|---|---|
| 14 | 0 | 1 | 1 | 4 |
| 15 | 0 | 1 | 1 | 3 |
| 16 | 0 | 1 | 1 | 4 |
| 17 | 0 | 1 | 1 | 3 |
| 18 | 0 | 1 | 1 | 5 |
| 19 | 0 | 1 | 1 | 1 |
| 20 | 0 | 1 | 1 | 4 |
| 21 | 0 | 1 | 1 | 4 |
| 7 | 0 | 2 | 1 | 5 |
| 8 | 0 | 2 | 1 | 3 |
| 9 | 0 | 2 | 1 | 3 |
| 10 | 0 | 2 | 1 | 4 |
| 11 | 0 | 2 | 1 | 3 |
| 12 | 0 | 2 | 1 | 3 |
| 13 | 0 | 2 | 1 | 4 |
| 14 | 0 | 2 | 1 | 4 |
| 15 | 0 | 2 | 1 | 5 |
| 16 | 0 | 2 | 1 | 2 |
| 17 | 0 | 2 | 1 | 3 |
| 18 | 0 | 2 | 1 | 5 |
| 19 | 0 | 2 | 1 | 2 |
| 20 | 0 | 2 | 1 | 4 |
| 21 | 0 | 2 | 1 | 3 |
| 7 | 0 | 3 | 0 | 4 |
| 8 | 0 | 3 | 0 | 3 |
| 9 | 0 | 3 | 0 | 4 |
| 10 | 0 | 3 | 0 | 2 |
| 11 | 0 | 3 | 0 | 2 |
| 12 | 0 | 3 | 0 | 3 |
| 13 | 0 | 3 | 0 | 4 |
| 14 | 0 | 3 | 0 | 3 |
| 15 | 0 | 3 | 0 | 4 |
| 16 | 0 | 3 | 0 | 2 |
| 17 | 0 | 3 | 0 | 3 |
| 18 | 0 | 3 | 0 | 5 |
| 19 | 0 | 3 | 0 | 2 |
| 20 | 0 | 3 | 0 | 5 |
| 21 | 0 | 3 | 0 | 3 |
| 7 | 0 | 4 | 0 | 4 |
| 8 | 0 | 4 | 0 | 3 |
| 9 | 0 | 4 | 0 | 5 |
| 10 | 0 | 4 | 0 | 4 |
| 11 | 0 | 4 | 0 | 4 |
| 12 | 0 | 4 | 0 | 3 |
| 13 | 0 | 4 | 0 | 5 |
| 14 | 0 | 4 | 0 | 4 |

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|---|---|---|---|---|
| 15 | 0 | 4 | 0 | 2 |
| 16 | 0 | 4 | 0 | 4 |
| 17 | 0 | 4 | 0 | 3 |
| 18 | 0 | 4 | 0 | 5 |
| 19 | 0 | 4 | 0 | 3 |
| 20 | 0 | 4 | 0 | 3 |
| 21 | 0 | 4 | 0 | 4 |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 | 4 |
| 3 | 1 | 1 | 1 | 4 |
| 4 | 1 | 1 | 1 | 3 |
| 5 | 1 | 1 | 1 | 4 |
| 6 | 1 | 1 | 1 | 5 |
| 1 | 1 | 2 | 1 | 4 |
| 2 | 1 | 2 | 1 | 2 |
| 3 | 1 | 2 | 1 | 2 |
| 4 | 1 | 2 | 1 | 3 |
| 5 | 1 | 2 | 1 | 5 |
| 6 | 1 | 2 | 1 | 4 |
| 1 | 1 | 3 | 0 | 1 |
| 2 | 1 | 3 | 0 | 4 |
| 3 | 1 | 3 | 0 | 5 |
| 4 | 1 | 3 | 0 | 5 |
| 5 | 1 | 3 | 0 | 5 |
| 6 | 1 | 3 | 0 | 4 |
| 1 | 1 | 4 | 0 | 5 |
| 2 | 1 | 4 | 0 | 5 |
| 3 | 1 | 4 | 0 | 5 |
| 4 | 1 | 4 | 0 | 5 |
| 5 | 1 | 4 | 0 | 4 |
| 6 | 1 | 4 | 0 | 4 |

| Evaluator | Specialist | Project | Human | VIABILITY |
|---|---|---|---|---|
| 7 | 0 | 1 | 1 | 3 |
| 8 | 0 | 1 | 1 | 3 |
| 9 | 0 | 1 | 1 | 5 |
| 10 | 0 | 1 | 1 | 5 |
| 11 | 0 | 1 | 1 | 3 |
| 12 | 0 | 1 | 1 | 2 |
| 13 | 0 | 1 | 1 | 3 |
| 14 | 0 | 1 | 1 | 4 |
| 15 | 0 | 1 | 1 | 3 |
| 16 | 0 | 1 | 1 | 5 |
| 17 | 0 | 1 | 1 | 3 |
| 18 | 0 | 1 | 1 | 5 |

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|---|---|---|---|---|
| 19 | 0 | 1 | 1 | 1 |
| 20 | 0 | 1 | 1 | 5 |
| 21 | 0 | 1 | 1 | 4 |
| 7 | 0 | 2 | 1 | 4 |
| 8 | 0 | 2 | 1 | 3 |
| 9 | 0 | 2 | 1 | 5 |
| 10 | 0 | 2 | 1 | 5 |
| 11 | 0 | 2 | 1 | 4 |
| 12 | 0 | 2 | 1 | 2 |
| 13 | 0 | 2 | 1 | 3 |
| 14 | 0 | 2 | 1 | 5 |
| 15 | 0 | 2 | 1 | 5 |
| 16 | 0 | 2 | 1 | 4 |
| 17 | 0 | 2 | 1 | 3 |
| 18 | 0 | 2 | 1 | 5 |
| 19 | 0 | 2 | 1 | 2 |
| 20 | 0 | 2 | 1 | 4 |
| 21 | 0 | 2 | 1 | 3 |
| 7 | 0 | 3 | 0 | 3 |
| 8 | 0 | 3 | 0 | 4 |
| 9 | 0 | 3 | 0 | 3 |
| 10 | 0 | 3 | 0 | 4 |
| 11 | 0 | 3 | 0 | 3 |
| 12 | 0 | 3 | 0 | 2 |
| 13 | 0 | 3 | 0 | 4 |
| 14 | 0 | 3 | 0 | 5 |
| 15 | 0 | 3 | 0 | 5 |
| 16 | 0 | 3 | 0 | 3 |
| 17 | 0 | 3 | 0 | 3 |
| 18 | 0 | 3 | 0 | 5 |
| 19 | 0 | 3 | 0 | 3 |
| 20 | 0 | 3 | 0 | 5 |
| 21 | 0 | 3 | 0 | 4 |
| 7 | 0 | 4 | 0 | 3 |
| 8 | 0 | 4 | 0 | 2 |
| 9 | 0 | 4 | 0 | 5 |
| 10 | 0 | 4 | 0 | 5 |
| 11 | 0 | 4 | 0 | 5 |
| 12 | 0 | 4 | 0 | 2 |
| 13 | 0 | 4 | 0 | 4 |
| 14 | 0 | 4 | 0 | 5 |
| 15 | 0 | 4 | 0 | 4 |
| 16 | 0 | 4 | 0 | 4 |
| 17 | 0 | 4 | 0 | 3 |
| 18 | 0 | 4 | 0 | 5 |
| 19 | 0 | 4 | 0 | 4 |

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|---|---|---|---|---|
| 20 | 0 | 4 | 0 | 3 |
| 21 | 0 | 4 | 0 | 3 |
| 1 | 1 | 1 | 1 | 2 |
| 2 | 1 | 1 | 1 | 3 |
| 3 | 1 | 1 | 1 | 3 |
| 4 | 1 | 1 | 1 | 3 |
| 5 | 1 | 1 | 1 | 2 |
| 6 | 1 | 1 | 1 | 4 |
| 1 | 1 | 2 | 1 | 4 |
| 2 | 1 | 2 | 1 | 5 |
| 3 | 1 | 2 | 1 | 3 |
| 4 | 1 | 2 | 1 | 5 |
| 5 | 1 | 2 | 1 | 4 |
| 6 | 1 | 2 | 1 | 4 |
| 1 | 1 | 3 | 0 | 2 |
| 2 | 1 | 3 | 0 | 1 |
| 3 | 1 | 3 | 0 | 5 |
| 4 | 1 | 3 | 0 | 2 |
| 5 | 1 | 3 | 0 | 5 |
| 6 | 1 | 3 | 0 | 5 |
| 1 | 1 | 4 | 0 | 4 |
| 2 | 1 | 4 | 0 | 3 |
| 3 | 1 | 4 | 0 | 5 |
| 4 | 1 | 4 | 0 | 4 |
| 5 | 1 | 4 | 0 | 5 |
| 6 | 1 | 4 | 0 | 4 |