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Creativity Triggers

an Extension and an Empirical Evaluation of their Effectiveness during Requirements Elicitation

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Creativity Triggers: an Extension and an Empirical Evaluation of their Effectiveness during Requirements Elicitation

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Chapter 1

Introduction

In a changing society, creativity has emerged as a key factor in businesses which has direct consequences in the way engineers lead *Requirements Engineering* (RE). Across the literature, the pieces of evidence are multiple and all confirming this importance. In [**4**], The *Nomura Institute*[1] states that *"Creativity will be the next economic activity, replacing the current focus on information"*. According to Brown [**11**], the challenge nowadays for all companies and industries is to be creative in order to stay competitive. Additionally, the need for creativity also arises due to the emergence of new Information and Communication Technologies (ICT). This emergence comes with new forms of organisations, new lifestyles and new works. As a direct consequence, organisations are trending towards creative thinking to create new types of added value [**5**].

This shift toward creativity clearly translates into a need for incorporating creativity in RE [**4**] to ultimately design new innovative products or services. Today, more and more authors agree and recognize that RE is a creative process. In [**2**], Maiden and Robertson present RE as being *"a creative process in which stakeholders and engineers work together to create ideas for new systems that are eventually expressed as requirements [. . .]. The importance of [creativity] is expected to increase over the next decade"*. The idea that RE should include creativity is also supported by Nguyen and Swatman in [**13**] while other pieces of works [**12**, **13**] have demonstrated the creative essence of RE processes [**5**]. Authors have recognized creativity as one central aspect that every practitioner should be able to incorporate in RE processes.

Given that creativity and RE are closely intertwined, there is a clear opportunity to develop tools that would support creative thinking in RE. However, this field of study is at its very first stages and a lot of authors have asserted a need to lead further researches. Although some tools exist and support creativity in RE, they require a heavy implementation and they thus restrict their use. To face this issue, a lightweight creativity tool was presented in [**1**], namely the *Creativity Triggers* (CT).

The lightweight tool wants to trigger creative thinking for stakeholders and RE practitioners. The fundamental goal is to have an "easy-to-use" tool to create creative requirements. Practically speaking, the Creativity Triggers is a cards deck. Each card is a Creativity Trigger on its own and represents one quality of a product, service or idea considered as innovative. It presents an illustration and an explanation of the quality. The authors of [**1**] mention that the quality refers somehow to a non-functional requirement. Such qualities do not refer to the functionality of a product, they reflect a general ability that products or services have, for

[1] The *Nomura Institute is the biggest management and economic consulting firm based in Japan.*

instance "being fast".

The CT design as presented in [**1**] is still at an exploratory stage and its authors have outlined some limitations that need to be solved like the validation of the completeness of the tool. In our work, we try to address some of these limitations. We take the CT as a starting point to further develop the tool. Our contribution is two-fold: on the empirical side, we do the study that creates the tool again to increase the number of Creativity Triggers and to enhance its representativeness. Furthermore, we validate the tool more systematically in a practical case. On the other side, we develop a concrete methodology to provide guidelines to the RE practitioners on how to use the tool.

The remainder of this work is structured in five chapters.

In Chapter 2, we present the context of our work and its theoretical prerequisites. In Section 2.1 Requirements Engineering, we define the field of interest and we present the steps that compose the Requirements Engineering process. In Section 2.2 Creativity, we define the creativity and its components, we outline the importance of Creativity in Requirements Engineering and we show how to assess creativity in Requirements Engineering.

In Chapter 3, we review the literature. In Section 3.1 Related paper, we succinctly introduce the paper that presented, on an exploratory basis, the Creativity Triggers in the literature. In Section 3.2 How to support creative thinking in RE, we expose some techniques and tools from the literature that support creative thinking in Requirement Engineering.

In Chapter 4, we explain the empirical part of our work. In Section 4.1 Methodology, we outline the methodology that we followed for this part. In Section 4.2 Results, we present our revised Creativity Triggers and a methodology to use the tool.

In Chapter 5, we validate the tool with a real and professional case. We precise the methodology used to lead the validation in Section 5.1 Methodology and the results in Section 5.2 Results.

In Chapter 6, we conclude by summarizing our findings in Section 6.4 Conclusion, by presenting the limitations of our work in sections 6.1 Limitations due to study design and 6.2 Limitations due to data treatment, and by proposing future works in Section 6.3 Future researches.

Chapter 2

Theoretical background

As mentioned in section 1 Introduction, the tool stands to make the RE process more creative. In the first instance it is essential to define the concepts of interest on a theoretical basis. In the following of the section, we recall what Requirements Engineering (RE) is and which steps compose the RE process. We then present some insights from the literature to define the concept of creativity. With both concepts defined, we are thereupon able to demonstrate more precisely why creativity is important in RE and how it is captured.

2.1 Requirements Engineering

2.1.1 Definition

To understand the context where Creativity Triggers take place, we need to recall succinctly what a *requirement* is to then properly define RE. In the literature, we can find several definitions of this topic. To facilitate the understanding of the reader, we have chosen one definition of RE from the literature and we will use it for the remainder of this paper. In the subsequent paragraphs, we present the definition and its components.

RE is built around the concept of requirement. To understand this latter, Pohl gives a precise definition specifying three different senses in [**19**]. A requirement is:

1. *"A condition or capability needed by a user to solve a problem or achieve an objective"*
2. *"A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification or other formally imposed document"*
3. *"A documented representation of a condition or capability as in (1) or (2)"*

We can now better understand the definition of RE given by Nuseibeh and Easterbrook in [**18**]. They designate the RE process as an iterative process that discovers the requirements of a system by identifying the involved stakeholders along with their needs. The purpose is to create a document that contains the discovered requirements in a way that allows analysis, communication and implementation. More formally, they state that RE is: *"The branch of* [...] *engineering concerned with the real-world goals for, functions of, and constraints on* [...] *systems. It is also concerned with the relationship of these factors to precise specifications of* [systems] *behavior, and to their evolution over time and across* [systems] *families"*.

Nuseibeh and Easterbrook explain more in details three major components of that definition:

1. *"The real-world goals"*: they refer to the *why* and the *what* of the system.
2. *"Precise specifications"*: they allow future analysis, validation and verification.
3. *"Evolution over time and across* [system] *families"*: it permits to fit a dynamic environment and to reuse past specifications.

2.1.2 Steps

There is no universal consensus on the different steps that compose the RE process but authors generally converge to the same underlying ideas. Once again, to promote a greater understanding, we will acknowledge and use the steps described in [**19**] for the remainder of this paper. The main point of this section is to understand the context in which creativity occurs and to better outline in which step(s) CT seem to be the more useful.

In [**19**], Pohl presents four steps as depicted in Fig. 2.1:

1. The *elicitation*: this is the first step which allows to master the environment and the problem of interest. During elicitation, the RE practitioner discovers the requirements, the needs and the constraints relating to the system to-be. This stage does not restrict itself to only capture the requirements expressed by the stakeholders. Sometimes, the practitioner must uncover requirements or needs that the stakeholders have but for which they are not explicitly aware of. It makes the elicitation step more complex and exploratory. This is the reason why Creativity Triggers are mainly useful in this step. Indeed, they provide support to better lead the discussion in which unawareness will be uncovered.
2. The *negotiation*: in this stage, the stakeholders of a project must reach an agreement about the requirements. This is particularly difficult since stakeholders do not have the same background, responsibilities and objectives. Moreover, for each highlighted conflict, a solution must be found during negotiation.
3. The *specification*: this step consists in writing out as formally as possible a requirements document which will be used for the next stages. In general, the output of the task is seen as one monolithic document which contains all final requirements. In contrast, Pohl considers that the document must be one *"bunch of models"* that integrates firstly the point of view of all stakeholders and secondly the final and the intermediate requirements [**19**].
4. The *validation* and *verification*: there is a fundamental difference between validating and verifying the requirements. Pohl presents the validation as the answer to the following question: *"am I building the right product?"* [**19**]. During this step, the RE practitioner validates whether the resulting requirements and the wishes of the stakeholders are consistent. On the other hand, Pohl sees the verification as the following question: *"am I building the product right?"* [**19**]. In other words, the verification is the stage where the engineer verifies if the final requirements match the constraints of the environment.

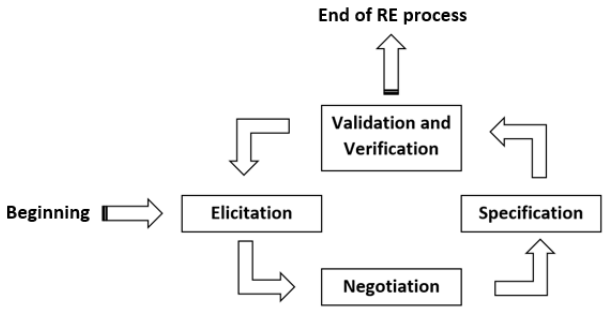

Figure 2.1: The four steps of the RE process

Fig. 2.1 illustrates the steps of the RE process and depicts its iterative aspect. The RE process can be seen as a series of iterations. At each iteration, we either refine the requirements found at the previous iteration, or we pivot the direction of our work because we were not complying with the needs of the stakeholders. In a case of a pivot, we may change significantly our viewpoint and we may start to consider completely new ideas. CT can support this shift.

We only have presented a general overview of RE process to allow the reader to understand the background of the Creativity Triggers. If the reader wants more details about RE, he can refer to [**18**, **19**].

2.2 Creativity

2.2.1 Definition

At first sight, the term *creativity* seems trivial and common to almost all individuals. Actually, its definition is not so straightforward and involves a lot of precise concepts. After reviewing the literature, we present here the main definitions and components associated with creativity.

According to [**4**] [**5**] [**9**], creativity is a mental process which aims to produce ideas or concepts. The outcome of this process has two main characteristics: the *usefulness* and the *novelty*. First of all, it needs to be useful. It means that the newly created ideas or concepts must be appropriate to the task. In [**8**], Charyton et al. define the usefulness as the *"functionality, the practicality and the applicability"* of the idea. Relative to RE, a requirement will be useful when it solves a problem matching the constraints of the environment. Secondly, the ideas or the concepts need to be novel. They must bring something new arousing a kind of unexpectedness. This is often referred to the "originality" of the solution. In [**14**], Boden brings three nuances to have a better understanding of the term "novel". A novel idea can bring something new according to the inventor, to its social group or to Humans as a whole. Based on these distinctions, Boden splits the creativity in 3 types:

1. The *psychological creativity* intends to create something that is new to the person who comes up with the idea but not to some others. This type of creativity is thus identified at the level of the individual.

2. By refining the psychological creativity, Gero et al. in [**16**, **17**] come with: the *situated creativity*. In this type, the newly generated idea is evaluated as creative regarding a particular social group or a specific situation. We can talk about a situated creativity

in RE, when the creative requirement is new to the stakeholders involved in the project, without being new historically speaking.

3. Finally, the *historical creativity* produces an idea that is new to the human being, to the human history [**15**]. This creativity relates on a historical and cross-cultural level. [**5**]

In RE, the historical creativity along with the situated creativity are characterized as collaborative creativity among the RE practitioners [**23**]. Mahaux et al. present in [**23**] a list of factors that emphasizes how the group influences the creativity. In addition, the collaborative creativity allows engineers to discover innovative products or services that generate new value for a company (with the situated creativity) or for the entire community (with the historical creativity) [**5**]. On the other hand, the psychological creativity is a means *"to educate, encourage and motivate individuals"* to become creative RE practitioners [**5**].

The CT mainly provoke the situated creativity where the ideas or the concepts are new to the situation which is the specific RE project. However, it is straightforward to understand how the Creativity Triggers can also reach the psychological and the historical creativity.

All in all, creativity is a mental process which aims to produce novel and useful ideas or concepts. Bourgeois-Bougrine et al. present the underlying resources of the creative process in [**9**] as: *"certain aspects of the intelligence, knowledge, cognitive styles, personality, motivation, affect, and physical and sociocultural environment context"*. In [**7**], the framework of Treffinger et al. is presented and divides the creative process in four steps:

1. *Generating Ideas*, during which divergent thinking[1] is applied,
2. *Digging deeper into Ideas*, where convergent thinking[2] is applied,
3. *Openness and Courage to Explore Ideas*,
4. *Listening to One's Inner Voice* which consists in reflecting around a specific idea.

As already mentioned before, the outcome of the process can be creative concepts or ideas. The practical implementation of the creative outcome is called "innovation". When we want to apply a creative process on a specific problem, there are three practical ways that can be followed depending on the type of outcomes we want to reach. These distinctions create three practical categories [**3**]: the *exploratory*, the *combinatorial* and the *transformational* creativity.

1. Exploratory creativity: this type refers to the exploration of the space of possible ideas. After the exploration, the inventor comes with a new creative idea. This is the creativity that is targeted by techniques like brainstorming or analogical reasoning. Assuming a RE process is done and we have one initial product called Product A. If we redo the RE process but now by applying an exploratory creativity process, we will come up with a new product, Product B. Although the Product B differs from the Product A, both products take place in the same context with the same constraints. In this example, Product A and Product B emerge from what is call the same conceptual space.

[1]Divergent thinking is a process that aims to produce creative ideas by considering as many solutions as possible. This is characterized by an unsupervised and unorganized context to ensure that ideas are randomly generated.

[2]Convergent thinking is opposed to divergent thinking. The process aims to answer standard and organized questions to generate non-creative and standard answers that solve a problem.

2. Combinatorial creativity: in this category, new ideas are created by using a combination and a synthesis of already existing ideas. The improbability of the combination will determine how much the idea will be creative.

3. Transformational creativity: in contrast with the exploratory creativity, the transformational one consists in changing the conceptual space by deleting or modifying the constraints. Subsequently, the inventors start to consider new ideas that were initially unreachable to still solve the same problems.

The Creativity Triggers refer mainly to the exploratory category. The central way of using the CT allows the people to uncover the space of possible ideas and thus to reach exploratory creativity. However, we will see in Section 4.2.2 Creativity Triggers methodology some alternative ways to use the CT that also allow to reach the combinatorial and the transformational creativity.

All concepts presented above allow us to define the creativity in a general way. In [**24**], Mahaux et al. suggest that such general definition is not sufficient to complete RE projects successfully. They agree that creativity is essential in the field of interest. However, they argue that the underlying definition of creativity varies from one RE project to another. Therefore, they present a framework in [**24**] to help the engineer defines the creativity within his own project. According to Mahaux et al., three contextual factors and five dimensions influence this definition. The three factors are: the *culture*, the *application domain* and the *resources*. While the five dimensions are: the *creative group*, the *field*, the *size of the novelty increment*, the *performance and product-orientation* and the *problem-finding and problem-solving orientation*. For each of these elements, the authors propose to the engineer interesting questions that may lead him to reason about the creativity and to ultimately define creativity within his RE project.

2.2.2 Importance in RE

In Chapter 1 Introduction, some preliminary insights are presented to find out why creativity is important in RE. This need is clearly highlighted by the scientific sphere. Incorporating creativity in RE has become so essential to that the educational sphere has also acknowledged its importance. In [**7**], Daly, Mosyjowski and Seifert state that the *"dependence of engineering progress on creativity is evident"*, they assert a lack of creativity training in current Engineering courses and they therefore present a framework to integrate this aspect in the curriculum. The idea is also supported in [**8**] where a survey is conducted to assess the creativity in Engineering courses. This recognition from the educational world emphasizes the relevance of creativity in the engineering field.

Now that RE and creativity are well defined, we can develop more precisely why creativity is central in the RE field. There are two main reasons behind the importance of creativity: first, to be competitive and second to anticipate problems and needs.

First of all, creativity is the root element to bring innovation and subsequently competitiveness within a business. As mentioned before, the current focus on creativity forces companies to compete on the market with useful and novel products and services. [**2**, **8**]

Secondly, creativity allows companies to anticipate future customers' needs. According to [**10**], RE process is traditionally about *"problem of scoping, understanding activity and finding the right product requirements for what the stakeholder states"*. When creativity is incorporated in RE, the process becomes exploratory and shifts to *problem discovery* and to *problem*

solving instead of problem of scoping. In other words, creativity allows to bring a solution for an unknown problem. If we extrapolate the underlying mechanism, creativity can uncover new needs in the market and thus identifying new business opportunities. In [**4**], Maiden et al. explain that innovative technologies have often emerged before the market need. To come up with such products, exploration is needed to uncover the unconscious users' needs, exploration that is well supported by creativity and by the CT.

2.2.3 How to capture Creativity in RE

Now that the reader understands the importance of creativity in the engineer field, we can focus on how to capture the creativity in a RE context. Obviously, some tools that assess creativity in a general context exist but few of them stand to assess the creativity in a specific engineering environment. One of them is called CEDA and is presented in [**8**]. The main purpose of *Creative Engineering Design Assessment* (CEDA) is to evaluate the creativity and the usefulness of a particular engineering design. In [**8**], Charyton et al. point out the need to conduct more research about the current topic.

Chapter 3

Literature review

3.1 Related paper

Our work is a direct consequence of the paper of Burnay et al.: *"Stimulating Stakeholders' Imagination: New Creativity Triggers for Eliciting Novel Requirements"* [**1**] as mentioned in Chapter 1 Introduction. The paper leads preliminary research on the Creativity Triggers. The purpose was two-fold; first *"to gain better insight into the concept of creativity triggers"* [**1**], then to prove that there is an opportunity to deeper develop the Creativity Triggers. The paper is exploratory and the authors recognize a need to lead further research on the topic of Creativity Triggers. Consequently, our work stands for that reason.

In the remainder of our work, we take for granted the definition of the Creativity Triggers and the assumptions validated and presented in [**1**]. However, to ensure the comprehension of the reader, we recall the main elements of the related paper.

In [**1**], two focus groups were run to determine four guidelines used to design the Creativity Triggers and three ideas determining the way of using the Creativity Triggers. We acknowledge the four guidelines and the three ideas for our work. Please refer to the *Section III – B. Main Observations* of [**1**] for any details. In this section, we explicitly specify when one of our tasks is drawn from the paper [**1**] and we indicate how we contribute to what was done in [**1**].

The authors recognize a series of limitations and future questions that need to be answered. Our work tries to address some of them. They are mainly the followings:

- To identify more Creativity Triggers
- To validate them more systematically
- To validate the correctness and the completeness of the triggers
- To position more precisely the triggers in their context among the existing tools
- To provide a methodology that specifies how to use the tool

3.2 How to support creative thinking in RE

The main concern is to find out how to support and to provoke creative thinking during RE. We can identify two categories of support which fulfil that purpose: the *creative techniques* and the *creative tools*. In the subsequent section, we define the two categories, we highlight them

with some illustrations from the literature and we present how the Creativity Triggers differ from the presented techniques and tools.

Broadly speaking, the Creativity Triggers can be distinguished from all creativity techniques by being a tool instead of a technique. By *technique* we want to include everything that gives general guidelines or steps to be applied without giving any physical or concrete support or tool. We mean a workshop, a framework, a process, or even a methodology. Thus, the outcome of the technique relies on the interpretation of the practitioner who will put the technique into practice with his own influence. This involves that the technique can easily be biased in contrast with a tool. The latter is more specific than a technique. It is sometimes a concrete or a physical materialisation of a technique. A tool is a practical support, in contrast with conceptual guidelines, that stands on its own leaving less room to the interpretation of the user. About the existing tools, most of them require a heavy implementation and are too specific. the Creativity Triggers differ from them by being a lightweight and general tool.

3.2.1 Creative techniques

To support the creative thinking, an abundance of techniques exist. Many of them are very general and support creativity in the broadest sense like the *Six hats of thinking* of Edward de Bono. These techniques are thus not specific to RE. In what regards our field of interest, some of the general techniques have been derived to a specific use in a RE while others have been created from scratch especially for RE. In what follows, we present three of them: the *EPMcreate Technique* [**20**], a combinational framework [**22**] and *RESCUE* [**2**].

Mich et al. present the EPMcreate Technique in [**20**] to handle creativity in RE. The technique relies on the Elementary Pragmatic Model (EPM) which is a *"model of the pragmatics of communication"* [**20**] used by psychotherapists. By applying EPMcreate, the RE practitioners are able to identify the position of several stakeholders on multiple topics and to combine them. The newly created combination is a new position from which creative ideas can be generated.

EPMcreate is limited by two elements: the number of steps the practitioners need to implement and its scalability. Indeed, the technique is quite heavy to implement and need to be applied for each different pairs of stakeholders which can rapidly be overwhelming as the number of stakeholders increases. The Creativity Triggers differ from EPMcreate by being a lightweight tool and also by its independence over any stakeholder's network.

The framework presented in [**22**] allows the practitioners to incorporate combinational creativity in the RE process to generate new requirements in an automated way for a system that already exists. The principle of the framework is quite straightforward: it identifies *"familiar ideas and makes unfamiliar connections of those ideas.* [...] *New requirements are generated from the unfamiliar combination"* [**22**].

The limitations of the framework are multiple and allow us to stand our Creativity Triggers out from the current framework. First of all, the framework can only be applied with systems that already exist, that are not at their early stages and that include a large group of stakeholders. On the other hand, the Creativity Triggers are designed to be useful for both new and existing products or services even if with a small group of stakeholders. The second limitation is the dependency of the framework on what Bhowmik et al. call *"the reliable projection of the stakeholders' social interaction"* [**22**] which is not the case for our Creativity Triggers. Finally, they noticed in [**22**] that the framework can sometimes generate less-meaningful requirements.

The last technique is RESCUE which stands for *Requirements Engineering with Scenarios for User-Centred Engineering* and is presented in [**2**] by Maiden and Robertson. They present RESCUE as a *"concurrent engineering process in which different modelling and analysis processes take place in parallel [...] to surface requirements and design ideas needed for use case specification"*. RESCUE is a workshop which takes place after the specification of the system boundaries. The workshop allows the incorporation of creativity in RE. For that purpose, it integrates several creativity techniques like brainstorming and analogical reasoning to deal with the exploratory, the combinatorial and the transformational creativity.

RESCUE is a comprehensive technique that can handle every kind of creativity. It has the main advantage of being robust and very useful for the practitioners. However, as a direct consequence of its completeness, the technique is time consuming and resources demanding. On their side, our Creativity Triggers can be used during a short period of time without requiring so much resources.

3.2.2 Creative tools

Even if tools offer more objectivity, there is a clear lack of tools to support creativity in RE. It makes the existence of Creativity Triggers even more important. Among the few existing tools, we decided to present *AnTiQue Module* [**21**] and the *D2C tool* [**25**].

AnTiQue Module presented in [**21**] aims to *"retrieve designs and implementations of web services that service providers designed for domains that are analogical to the current requirement problem"*. In practice, the tool identifies web services that are technically analogical from the one of interest but not strictly similar regarding the application domain. It is illustrated in [**21**] with the following example. Assuming the web service of interest is a *car parking place finder*, another web service that is not strictly similar but analogical technically speaking can be a *cinema tickets finder*. Indeed, both services do not handle the same object of interest (a car parking place for the first one, a cinema ticket for the second one) but the services deal with the same functionalities namely: find the object of interest, book the object of interest, and so on. By reviewing analogical web services, the tool allows practitioners to gather dissimilar pieces of information that can be applied for their service to ultimately specify more creative requirements.

The obvious limitation of AnTiQue Module is its restriction to be used in a context of web service thus restraining the scope of the tool. The Creativity Triggers are on the other hand more generic than AnTiQue Module, and can be used no matter the type of product or service of interest.

The approach followed to construct the *Design to Connect tool* (D2C) is well detailed in [**25**]. More generally, the tool consists in a deck of 46 cards which aims to help designers to generate new connections in products. A connection is defined as follows in [**25**]: *"an interface between parts or functions and can be virtual or physical, permanent or removable"*. Each card mainly contains the following elements: a *Product Consideration*, a *Heuristic* and a *Short Description*. Actually, each card relates to a particular heuristic which is a *"way to reduce or create connections or to add a value to a connection"* [**25**]. In practice, designers should use the tool *"to find many solutions to meet future connection issues in products"*.

Although the D2C tool is very similar to the CT, they differ on several aspects, namely: the *Goal*, the *Construction*, the *Semantics* and the *Methodology of use*. Both tools find their interest on the elicitation phase of RE since they allow to generate new idea and to meet new requirements. With regards to the D2C tool, the main objective is to create new connections

especially in design. On the other side, the goal of the CT tool is to generate idea and to support creative thinking in general during the RE process.

Another distinction can be made about the *construction* of the tools. To create the D2C tool, authors in [**25**] identified what they called *"considerations that influence the design of a connection"* using the *Connections Design Considerations* framework presented in [**26**]. Then they constructed heuristics around these considerations. In other words, the heuristics are built on the experiences of expert designers and on what stands in the literature. The construction of the CT is more empirical. To create CT, a survey is conducted to collect qualities that are somehow linked to creativity. The CT is then derived from the collected qualities. It will be further detailed in Chapter 4 Improving Creativity Triggers.

It leads to the next difference, the *semantics*. As already mentioned before, each card of the D2C tool is based on a heuristic. It makes them more specific to a function or to a characteristic of a product/service. By contrast, each CT is constructed around a quality linked to the creativity. Given that, they are more general than the D2C.

Finally, the CT sets itself apart from the D2C by presenting a concrete methodology that specifies various ways of using the CT, see Section 4.2.2 Creativity Triggers methodology.

3.2.3 Literature review summary

The following table gives a general summary of the techniques and tools previously presented in the chapter.

Techniques or tools	**Core concept**	**Advantages**	**Limitations**	**Differences with CT**
EPM create [**20**]	*"Model of the pragmatics of communication"*; combines multiple positions from stakeholders to generate new creative positions.	Based on psychological theory.	Scalability, heavy implementation and dependence on the stakeholders' network.	CT are a lightweighted tool and they are not dependent on the stakeholders' network.
Combinational frameword [**22**]	Creates unfamiliar connections of familiar ideas.	Automated generation and supports combinational creativity.	Only with existing products/services, and depends on the stakeholders' network.	CT also work with new solutions and they are not dependent on the stakeholders' network.
RESCUE [**2**]	Workshop that incorporates several creativity techniques.	Supports the three types of creativity.	Time- and resource-consuming.	CT are less demanding in time and in resources.
AnTiQue Module [**21**]	Generates new ideas from technically similar web services with different application domains.	Physical and automated support.	Only with web services.	CT are more generic; they do not require a specific type of product/service.
Design To Connect [**25**]	Generates new connections for products or services.	Physical support and lightweight tool.	Specific to functions or characteristics of products/services, no methodology of use.	CT are built on empirical qualities, they are more generic and they come with a methodology of use.

Table 3.1: Literature review summary

Chapter 4

Improving Creativity Triggers

4.1 Methodology

Based on the assumptions and on what they have done in [**1**], we decided to lead the creation process of the CT in three steps as suggested in [**1**]. First, we conducted a survey to collect qualities linked to innovation. We then processed data manipulation of the gathered qualities to determine the CT to be. Finally, as a result, we built the CT cards according to the framework of [**1**]. Each step is well detailed in the following sections.

4.1.1 Survey

The first step of our methodology consisted in spreading a survey to collect data. To fulfil this purpose, we designed an online survey which is still available at this link: `https://orsiam.unamur.be/triggers/content/InnovationSurvey-home.php`. Our target sample is "anyone", without any particular characteristics. We tried to get a sample as heterogeneous as possible. To do so, we spread the survey online: through social media, and through a specialised website called *Survey Circle*[1]. Moreover, we designed some flyers with a QR-code redirecting to the survey to spread it physically (Appendix A.1).

To implement the survey, we followed the same conceptual framework presented in [**1**], i.e., we designed our own survey using the same flow and the same questions of [**1**]. This choice was made for two reasons. First of all, [**1**] Burnay et al. created the framework of the survey as a direct consequence of the study they led. As mentioned in section 3.1 Related paper, we take for granted the results of their analysis in our work, and consequently, the reasons that led the authors to choose this framework are still relevant. Secondly, using the same framework allows us to reuse the data collected in [**1**] and to have a bigger set of data.

As such we implemented this framework from scratch using a HTML editor. We are aware of the existence of some tools that support the creation of online surveys. Nowadays, we can develop surveys without coding at all. Nevertheless, we made the explicit choice of an HTML editor to get more flexibility regarding the implementation. We were then able to personalize the survey in two ways. The first one is the part *Results* at the end of the survey. In this section, the participant has the opportunity to navigate through interactive results, we further elaborate on this aspect in the subsequent paragraphs. The second aspect is a dynamic button that follows the user through all the results part and that gives him the opportunity to submit

[1]This website stands to spread survey in a heterogeneous sample around the world depending on some characteristics that we can provide.

a new idea. Both aspects, the results part and the button, aimed to get multiple submissions from one single user. On the one hand, the results part makes the respondent be more involved in our study. On the other hand, the button gives him an easy way to fill the survey again. In the following of this section, we further elaborate each step of the survey. Please refer to Appendix A.2 to have a BPMN diagram that depicts the flow of the survey.

The very first step of the survey is the choice of the language. We designed the survey in French, Dutch and English to reach more people (Appendix A.3).

The next stage is a short description of the survey (Appendix A.4) that leads to the personal information page (Appendix A.5). This stage collects from the respondent the following pieces of information: the gender, the age, the country, the experience toward innovation and the behavior toward innovation (*conservator*, *late adopter*, *majority follower*, *early adopter* or *innovator*). However, this stage is optional.

The third step is the main part of the survey (Appendix A.6). We ask the user to give a solution (defined as a product, service or idea) that is innovative. We defined innovation as *"being novel compared to other solutions available at the same time"*. After that, the user is asked to provide from one to five qualities that make him consider the solution as innovative. We also ask him to provide a short explanation and an optional link to a picture of the solution.

The concluding stage of the survey first shows the current number of submissions and the threshold we want to reach to provide incentives to the user to submit again (Appendix A.7). Then, we present the results (Appendix A.8), namely the most quoted solutions and qualities and some graphical illustrations of the demographics of the sample. For instance, we present the distribution of innovative experience and behavior among our sample (Figure 4.1).

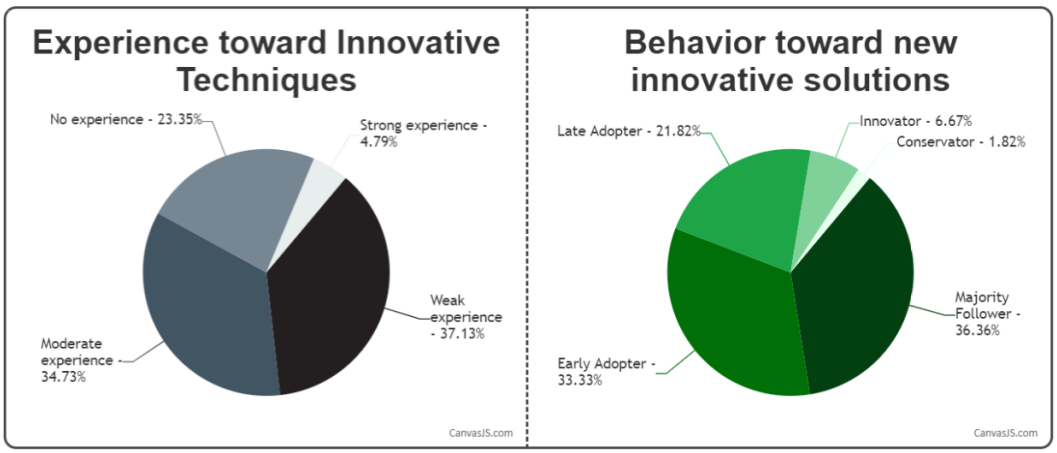

Figure 4.1: Innovative experience and behaviours

We strongly believe that presenting some solutions and qualities in the results would inspire the respondents and make them submit more ideas. A threat to that principle would be to skew the results. If all respondents submit the same quality that they just saw in the results, we would collect the qualities multiple times increasing wrongly its importance. However, the threat was not relevant in our case since we only focus on the fact that the respondent considers the quality as innovative, no matter if the quality comes from his mind or not. The same reasoning was applied for the qualities that we presented as examples in the statement of the survey.

The survey is then completed. The results in term of data is two-fold. On the first hand, we get pieces of information about the demographics and the experience of our sample. On the other hand, we get a list of qualities, each of them associated with a solution with its explanation and its optional illustration. In the following section, we present how we treated the collected data.

4.1.2 Data manipulation

The input of this part was the list of qualities collected with the survey. We gathered from 532 respondents a total of 1172 quality occurrences, that were reduced to 402 distinct qualities. The objective is to create clusters of similar qualities to reduce the list of qualities to the main aspects of innovation. We use Python and Power Query to fulfil this task. Python is used to manipulate the data while Power Query allows to explore the data. To do so, we proceed in three steps: the *preprocessing*, the computation of a *semantic similarity* and the creation of *clusters*.

Preprocessing

We collected qualities in French, English and Dutch. Since most Python libraries are in English, we translated the French and Dutch qualities. We corrected the spelling and we deleted the irrelevant qualities and errors. Since the "semantic similarity" approach only works between two words, and not sentences, we had to threat qualities composed of several words. We implemented a list of rules that we sequentially applied:

- If only one quality (adjective) was mentioned among the sentence, we manually extracted the quality.
- If there were multiple qualities (adjectives):
  - If it was a conjunction of distinct qualities (for instance, *effective and beautiful*), we considered them like two distinct qualities.
  - If one word perfectly summarized the input, we used this single word.
  - If not, we either arbitrarily choose one of the qualities mentioned or rejected the input.
- If no single word summarized the input and no quality (adjective) was included in the input, we rejected it.

Semantic similarity

The next task was to create a matrix of semantic similarity between all qualities. We did some research in the literature to find previous works on the semantic topic. We found several semantic metrics each with different advantages and downsides. In [**27**], a state of the art is done on seven semantic similarity metrics. To overcome the disadvantages of the seven metrics, a new one is proposed, called *Wpath*. We continue by theoretically presenting the metric.

The metric relies on Wordnet, a well-known taxonomy. Wordnet can be seen as a semantic network containing several English words. A node represents what is called a *synset* which is a list of words that share one common sense. An edge between two nodes denotes a *hypernymy* and *hyponymy* relationship[2]. In the taxonomy, more abstract concepts are located higher, while

[2]A hyponym is a word that shares a *type-of* relationship with another word, that is it hypernym. A car is a *type-of* vehicle. Therefore, car is the hyponym and vehicle is the hypernym.

more specific concepts are situated lower. For instance, the word *entity* is high and the word *car* is low in the taxonomy.

Wpath then *"encodes* [...] *the structure of the concept taxonomy and the statistical information of concepts"* to compute the semantic similarity [**27**]. In practice, the similarity is computed between two nouns or two verbs resulting in a number from 0 to 1; 0 represents the maximum dissimilarity while 1 represents a perfect similarity. Mathematically, the semantic similarity is a weighted sum of the *Path* technique and what is called the *Information Content* (IC). The *Path* returns the shortest path length between the compared words and their *Least Common Subsumer* (LCS). This is the most specific ancestor that is shared by the two compared words in Wordnet. *Path* is then weighted by the IC in two ways: considering IC as a *graph-based* IC and then as a *corpus-based* IC. First of all, a graph-based IC allows Wpath to include the knowledge structure in the similarity metric, in other words the level of abstraction of the concepts. More precisely, the IC of the LCS is included in a way that, for the same shortest path length, the similarity will be higher if the LCS is more specific (low in the taxonomy) compared to a more abstract LCS (high in the taxonomy). Indeed, a specific LCS contains more information than an abstract LCS. Secondly, a corpus-based IC of the compared concepts is included in the metric. It allows to incorporate corpus analysis in the similarity measure. It mainly consists in integrating analysis of word occurrence and analysis of context within the words are usually used.

The following manipulations in this section were done in Python, more precisely with the library *Sematch*[3] that allows to compute the Wpath metric using *Wordnet*.

The first issue was the fact that the metric only works between two nouns or between two verbs. Indeed in Wordnet each word has a *Part of Speech* (POS) which can be a for adjective, s for adjective satellite, n for noun, v for verb and r for adverb. Wpath only works between two nouns (n) or two verbs (v). Unfortunately we mostly collected adjective and adjective satellite with our survey. Therefore we decided to implement an *extraction* strategy to solve this issue.

Extraction The purpose was to return the closest noun from an adjective, an adjective satellite, a verb or an adverb to be able to compute the Wpath metric. In practice, we implemented four strategies used by trial and error. If the first strategy did not work, the second was used and so one. Namely the strategies are: *DerivForm*, *Attribute*, *Nounification* and *SimilarTos*.

1. DerivForm: the first strategy uses the concept of *derivationally related forms* of Wordnet. It returns from a given concept, a term that has the same root and the same semantic but a different syntactic category. However, each word of Wordnet does not necessarily have a *derivationally related form*. So the current strategy is not sufficient on its own.

2. Attribute: the method also relies on Wordnet, especially on the concept of *attribute*. The latter refers to a noun that expresses the same value than an adjective. This time again the attribute does not exist for each concept.

3. Nounification: the strategy implements a *nominalization* of adjective. A list of rules is applied to transform an adjective in a noun dealing with the suffix of each term.

4. SimilarTos: the last strategy uses the concept of *similar tos* from Wordnet. It returns a related synset similar in meaning to the given word.

[3]Sematch is an open-source library that allows the manipulation and the evaluation of similarity metrics in Python thanks to the use of Wordnet. It is available on GitHub on this link: `https://github.com/gsi-upm/sematch/blob/master/README.md`

Initially, we had 402 distinct qualities including: 226 nouns, 168 adjectives/adverbs/verbs, and 8 words which were not found in Wordnet. The extraction algorithm was quite effective as it worked successfully on 163 qualities out of the 168 that were not a noun. We handled manually the 5 remaining qualities. During the extraction phase, some qualities returned the same closest noun. As a direct consequences, we had 313 distinct nouns left for the remainder of the data manipulation. To illustrate the behavior of the extraction algorithm, here are some results:

- *pleasant* returned *pleasure* with DerivWord.
- *sure* returned *assurance* with Attribute
- *essential* returned *essentiality* with Nounification
- *user-friendly* returned *easiness* with SimilarTos

The last 8 inputs that were not found in Wordnet were: *"crowdfunding"*, *"business model"*, *"product service"*, *"high definition"*, *"good temperature"*, *"screen resolution"*, *"cout"*, *"cross-schematic"*. Since neither the preproccessing phase nor the extraction step worked on these inputs, we decided not to use them.

Semantic similarity matrix The last thing before computing the semantic similarity Wpath, was to specify which meaning of each word must be used. Indeed, some words only have one meaning while other can have several meanings. In the latter case, it was necessary to specify the meaning on which the similarity had to be measured in order to avoid ambiguities. For instance, the word *collaboration* has the two following definitions in Wordnet:

1. *"act of working jointly"*
2. *"act of cooperating traitorously with an enemy that is occupying your country"*

In the context of our study, it was clear that the first definition was targeted. We therefore analysed every word to specify as far as possible, the definition which had to be used when there was ambiguity.

Ultimately, we created a symmetric matrix of 313 rows and 313 columns containing the semantic similarity between all qualities. As a reminder, this metric ranges from 0 to 1: 0 stands for the maximum dissimilarity while 1 represents the maximum similarity.

Here are some insights to illustrate the final matrix:

- A subset of the matrix

Qualities	cheapness	smallness	portability	access	speed
cheapness	1.0	0.193	0.288	0.094	0.173
smallness	0.193	1.0	0.193	0.103	0.323
portability	0.288	0.193	1.0	0.094	0.173
access	0.094	0.103	0.094	1.0	0.506
speed	0.173	0.323	0.173	0.506	1.0

Table 4.1: The subset of the similarity matrix with the 5^{th} first qualities.

- In Table 4.2, the words similar to *accessibility* according to Wpath are presented. We can outline that the metric works quite well. Intuitively, the words which have a high similarity with *accessibility* effectively denote a common meaning.

Qualities	accessibility
accessibility	1.0
handiness	1.0
convenience	0.891
helpfulness	0.855
availability	1.0

Table 4.2: The most similar words to *accessibility*

Clustering

With a similarity measure between all qualities, we were able to group them into clusters. We are aware that specific clustering techniques exist like KMeans, Spectral Clustering or DBSCAN. However, we decided to implement a custom clustering technique to better fit the context of our work. The objective was to create clusters of qualities that respect the following statements:

- The similarity within a cluster is as high as possible.
- The similarity between distinct clusters is as low as possible.

To begin, we iterated on all qualities. For each of them, we created a group containing all the qualities similar to the first one with a similarity equal or greater than 0.8. By exploring our similarity matrix, we noticed that it was the second highest limit for a majority of qualities after the similarity of 1 (that every quality has, at least with itself). So, we initially chose the limit of 0.8. As a consequence, we got 313 groups of similar qualities. We reduced this number by applying several rules.

- If two groups were strictly identical, we only kept one occurrence of the group.
- If one group was contained in another one, we only kept the biggest group.
- If the group contained only one quality, we did not keep it.

Afterwards, we aggregated all groups that had words in common. For instance, assume we have the following groups:

1. [price, luxury]
2. [accessibility, handiness, convenience]
3. [cheap, price]
4. [helpfulness, accessibility, convenience]

We would then create a group that contains (1) and (3) (since they share the word *price*) and a second group with (2) and (4) (since they share the word *accessibility* and *convenience*). For each of these aggregated groups, we deleted duplicate qualities to have clusters of unique words. We analysed each cluster to assess its representativeness. When reading the cluster, we were able to outline the common sense shared by all its members. It was obvious for all clusters except for four clusters. Two clusters out the four were left due to their lack of representativeness and relevance to our task. The last two clusters were relevant but we denoted three distinct senses

within each of them. We applied a KMeans technique with a number of targeted cluster of three on each cluster to split them into smaller clusters. The objective was to extract the three meanings encapsulated in each cluster into smaller clusters containing only one sense. All in all, we got 20 clusters from our 313 distinct qualities.

We iteratively repeated this methodology with a limit of 0.79 and then with a limit of 0.75. The purpose was to identify the impact of modifying the limit. The resulting clusters were almost equivalent with 0.8 and 0.79. However, two new clusters appeared when applying the limit of 0.75. Since the two clusters were relevant with our work, we validated them.

At this point, we had 22 distinct clusters. The next step was to identify a centroid for each of them. The centroid is the most representative member of a cluster. In our case, the centroid would have been the word that is the most similar to the other words of its cluster. We fulfilled this task with our similarity matrix. When the method returned two centroids or a centroid that was not very striking, we manually selected another centroid.

The resulting clusters with their respective centroids are shown in Table 4.3.

№	**Clusters**	**Centroids**
1	Smallness, size, slightness, parsimony	Smallness
2	Beauty, prettiness, attractiveness, desirableness, fascination, good	Attractiveness
3	Amusement, entertainment, delight, joy, excitement	Amusement
4	Ecology, environment, physiology	Ecology
5	Autonomy, independency, freedom	Independency
6	Change, effect, difference, intuition, smell, feeling	Feeling
7	Playfulness, fun, humor, wittiness	Humor
8	Originality, novelty, freshness, newness	Freshness
9	Application, technology, high-technology	Technology
10	Portability, mobility, movability	Movability
11	Shock, surprise, disruption, amazement	Surprise
12	Creativeness, imaginativeness, creativity, design, conception, creation	Conception
13	Sleekness, perfection, polish, smoothness	Polish
14	Singularity, unexpectedness, oddness, uncommonness, strangeness, unusualness, unfamiliarity	Uncommonness
15	Coherency, cohesion, connection, interconnection	Cohesion
16	Evolution, development, hobby, connector, involvement, engagement, communication, relevance	Involvement
17	Intelligibility, interest, power, powerfulness, effectiveness, clarity, color	Powerfulness
18	Convenience, easiness, usability, simplicity, helpfulness, availability, utility, accessibility, handiness	Accessibility
19	Comfort, comfortableness, facilitation, assistance, ease, relaxation, delivery, service, help	Comfort
20	Ingenuity, quality, cleverness, resources, superiority	Ingenuity
21	Cheapness, luxury, price	Price
22	Contemporaneousness, up-to-dateness, timing	Up-to-dateness

Table 4.3: Resulting clusters

4.2 Results

In the following sections, we present how we used the result of Section 4.1.2 Data manipulation to build the Creativity Trigger cards. We present the improved Creativity Triggers and a methodology which helps the RE practitioner to use the tool.

4.2.1 Creativity Triggers results

The structure of our resulting CT respects the framework proposed in [**1**]. More precisely, each card of the tool is built around one quality linked to innovation which is ultimately the name of the card. Additionally, the card contains a short explanation of the trigger below the title. The section *"Consider also to..."* comes next. It provides some guidelines to support the thinking around the card and a visual symbol (at the center) to reflect the title of the card. Finally, the trigger proposes a section *"Example"* which intends to present a product or a service that is associated with the quality of the card. An explanation of the example demonstrates how the product or service effectively shares the quality and an illustration shows the product or service. We keep each card as simple as possible. Indeed, each card needs to be self-explanatory and the CT must remain a lightweighted tool.

Since each cluster depicted in Table 4.3 represents one aspect of innovation, we created one card for each cluster. The centroid is used as the name of the card. Some of the other members of the cluster are used in the section *"Consider also to..."* or *"Explanation"* and they are written in bold. It is important to notice that the clusters were built with the noun that we extracted (see Section 4.1.2 Data manipulation - Extraction). To create the cards, we used the initial qualities from which we extracted the nouns. For instance, the centroid *uncommonness* of the 14th cluster (Table 4.3) was extracted from the quality *uncommon*. Ultimately, the name of the card will be *uncommon*.

As a result, we created 22 cards which are presented here.

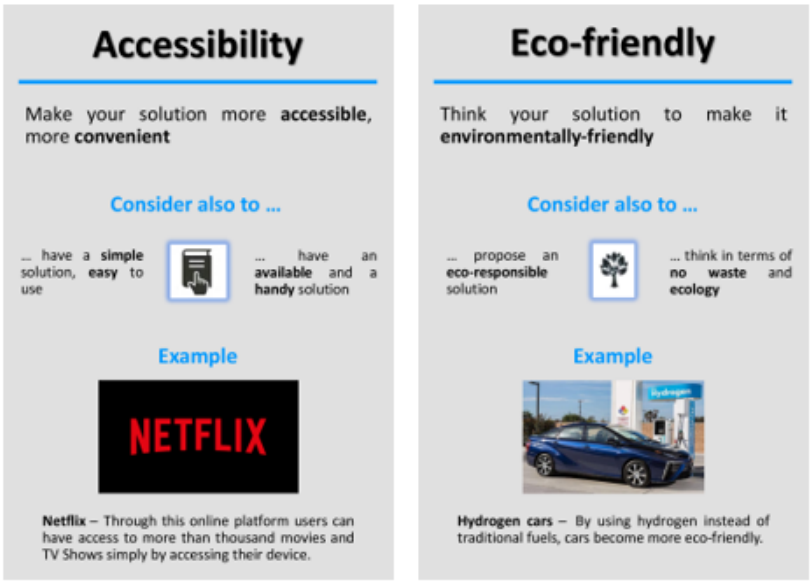

Figure 4.2: Creativity Triggers - 1 to 2

Refined

Adapt your solution to propose a **refined** aspect

Consider also to ...

... make your solution look **sleek** and **smooth**

... remove the **superfluous** visual elements

Example

Nest Thermostat – The thermostat adapts itself to the users' habits using machine learning. By automatically handling a lot, the interface can be reduced to the essential aspects only.

Powerful

Make your solution a symbol of **power** and **performance**

Consider also to ...

... have an **effective** solution

... raise the **interest** of the user

Example

Vacuum cleaner Dyson – Dyson is known for its power and effectiveness in cleaning which raise users' interest.

Involvement

Extend your solution to make the user more **involved**

Consider also to ...

... enhance the **link** between the user and your solution

... incorporate **communication** or **engagement** of the user

Example

Céramic CAFÉ – The café offers both a service and a product to the user. He can share a drink while taking part to the creation process of a ceramic object.

Ingenious

Think your solution to solve a problem **ingeniously**

Consider also to ...

... make your solution **superior**

... distinguish your solution from the competition by its **cleverness**

Example

Car jack – We cannot lift a car by hand. However, it can be done by the ingenuity of a car jack.

Uncommon

Find a feature that makes your solution **uncommon, unexpected**

Consider also to ...

... add an **unusual** feature that the competition does not offer

... adapt your solution to make it **odd** and **unfamiliar**

Example

Connected table – The function of the connected table goes beyond the traditional use of a table. The user does not expect this behavior.

Attractive

Make your solution more **attractive**, more **desirable**

Consider also to ...

... raise the user's **fascination** with an **intriguing** feature

... make your solution as **beautiful** as possible

Example

Cubic Robotics – This connected device interacts with the user and fulfils a lot of tasks. It is characterized by its attractiveness.

Figure 4.3: Creativity Triggers - 3 to 8

Cohesion

Integrate features to your solution that allow **cohesion**

Consider also to ...

... make the users **interconnected**

... think the solution to be **coherent**

Example

EFFENCY.

Effency – Effency is a digital fitness coach. It can handle fitness programs of sport teams and enhance the overall performance of a team.

Amusement

Find a feature that makes your solution **amusing, entertaining**

Consider also to ...

... make your solution more **delightful**

... add a feature that triggers the **excitement** or the **joy** of the user

Example

Virtual Reality – With the device, the user immerses himself in several universes to play various games.

Surprising

Make your solution more **surprising**, more **amazing**

Consider also to ...

... to **disrupt** the market

... to add a **shocking** feature

Example

3D food print – The device prints some food like pasta or chocolate with an amazing accuracy.

Smallness

Make your solution as **small** as possible, and **not cumbersome**

Consider also to ...

... reduce the **size** of the solution to make it easier to use

... propose a **slight** version of your solution

Example

PrinCube – The PrinCube is the smallest printer. You can print what you want where you want.

Comfort

Think your solution to enhance the **comfort** of the user

Consider also to ...

... propose some **assistance** or **help** for the user

... make your solution a source of **relaxation**

Example

Wireless headset – A wireless headset provides more freedom to the user. The comfort is enhanced with the noise cancelling feature.

Novelty

Extend your solution to make it **novel** or **fresh**

Consider also to ...

... **update** your solution

... add completly **new** features

Example

Autonomous car – With the autonomous behavior, the common concept of a car follows the evolution of progress.

Figure 4.4: Creativity Triggers - 9 to 14

Technology

Integrate somehow the **technology** to your solution

Consider also to ...

... use the **new technologies**

... use **Machine Learning**

Example

Smart watch – The technology handles a lot of functionnalities like making calls, tracking location and notifying health status.

Feeling

Extend your solution with features that elicit the **feelings** of the user

Consider also to ...

... stimulate the **five senses**

... add a feature that makes your solution **impactful**

Example

BBC iPlayer

BBC Player – With a BBC Player, the user can watch and feel his favorite movies or sport games again and again.

Independence

Make your solution more **independent**

Consider also to...

... make your solution **autonomous** to work on its own

... **free** your solution of complementary assets

Example

Photovoltaic panel – The house equipped with photovoltaic panels is able to produce on its own its electricity.

Conception

Think the **conception** of your solution to make it more **imaginative**

Consider also to ...

... review the **design** of the solution

... add a feature from your own **creation**

Example

Microsoft Surface – The Microsoft Surface, hybrid between a laptop and a tablet, is designed to integrate a tablet holder and a keyboard.

Humerous

Find a feature that makes your solution more **humerous**, more **funny**

Consider also to ...

... think to the **playful** side of your solution

... add some **witty** widgets

Example

Distorting mirror – The mirror reflects the original picture with some distortions. This fun feature makes the user laugh.

Price

Adapt the **price** of your solution to the target or propose various price offers

Consider also to ...

... promote a **cheap** image

... promote a **luxurious** image

Example

Flight ticket – The offer of flying tickets proposes a various range of prices. From low-cost to business class, the offer fits every need.

Figure 4.5: Creativity Triggers - 15 to 20

Figure 4.6: Creativity Triggers - 21 to 22

4.2.2 Creativity Triggers methodology

In this section, we propose a methodology that specifies how to use the Creativity Triggers in a RE project. More precisely, we present guidelines that need to be implemented in any Requirement Engineering projects. Then, we provide three specific methodologies of using the CT. Each of them aims to reach one of the three practical categories of creativity presented in Chapter 2 Theoretical background (see section 2.2.1 Definition), namely the exploratory, the combinatorial and the transformational creativity. Finally, we present a flow that integrate the three specific methodologies to combine the three creativity within the same project.

Before elicitation phase

This part comes right before starting the elicitation phase. The Figure 4.7 exposes a BPMN to show the flow of the current process (see Appendix B.1 for a full page version).

1. The deck of CT contains 22 cards. It is important to check that every card is relevant with the specific project. Since there is not yet a tool that objectively determines which card is relevant for a specific project, and in order to avoid a bias from the RE practitioner, a card can only be rejected if a statement of the project specifically states that the quality of a card is forbidden. If no rejection is obvious, we can keep the 22 cards for the project.
2. The RE practitioner must ensure that he understands every card.
3. The structure of a card must be explained to the stakeholders to make them familiar with the tool. If a card was rejected at step (1), the practitioner can use it, before the elicitation phase, to illustrate the tool and maybe to do a fictitious test.

4. For the remainder of the methodology, we assume that the RE project is divided into relevant modules, each of them dealing with a particular aspect of the solution (a product or a service) to-be.

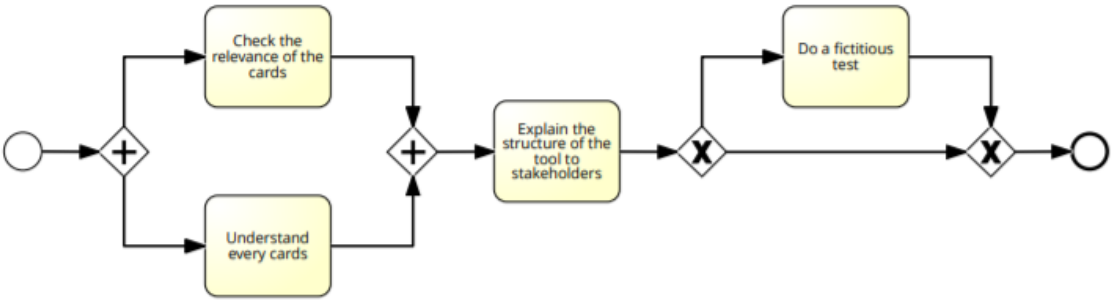

Figure 4.7: *Before elicitation process*

Methodology for exploratory creativity

The Figure 4.8 exposes a BPMN to show the flow of the current methodology (see Appendix B.2 for a full page version).

1. To begin with, each module of the project is reviewed without the Creativity Triggers. This step aims to identify the elementary requirements and to be more familiar with the environment of the project.

2. From now, the CT can be used for each module. It is important to sensitize the stakeholders that they have to make the solution competitive and to be creative.

3. For each module, the practitioner must expose the card to the stakeholders and let them read by themselves.

4. Then, he may ask which requirement(s) allow(s) the solution to share the quality of the card. This should lead to a discussion around the card.

5. The steps (3) and (4) must be repeated for every card that is relevant with the current module.

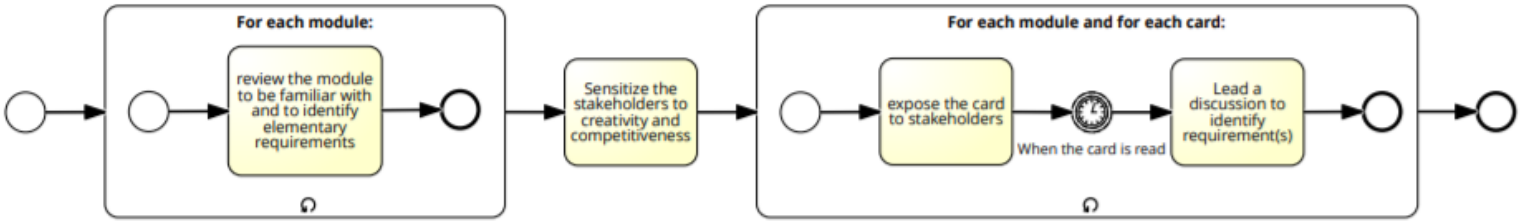

Figure 4.8: *Exploratory methodology process*

Methodology for combinatorial creativity

The Figure 4.9 exposes a BPMN to show the flow of the current methodology (see Appendix B.3 for a full page version).

1. For each module, the practitioner must process the *Methodology for exploratory creativity* in the first time.
2. For one specific module, the practitioner must choose 2 cards already used in step (1). More than 2 cards can be combined, but the complexity of the methodology increases with the number of card combined.
   (a) If the two cards had already generated new requirements (during the first step), the stakeholders are asked how to combine the two requirements to create a new one.
   (b) If the two cards did not have generated new requirements in step (1) or if the two new requirements cannot be combined directly, the user must ask which new requirement(s) would combine the two qualities in the solution.

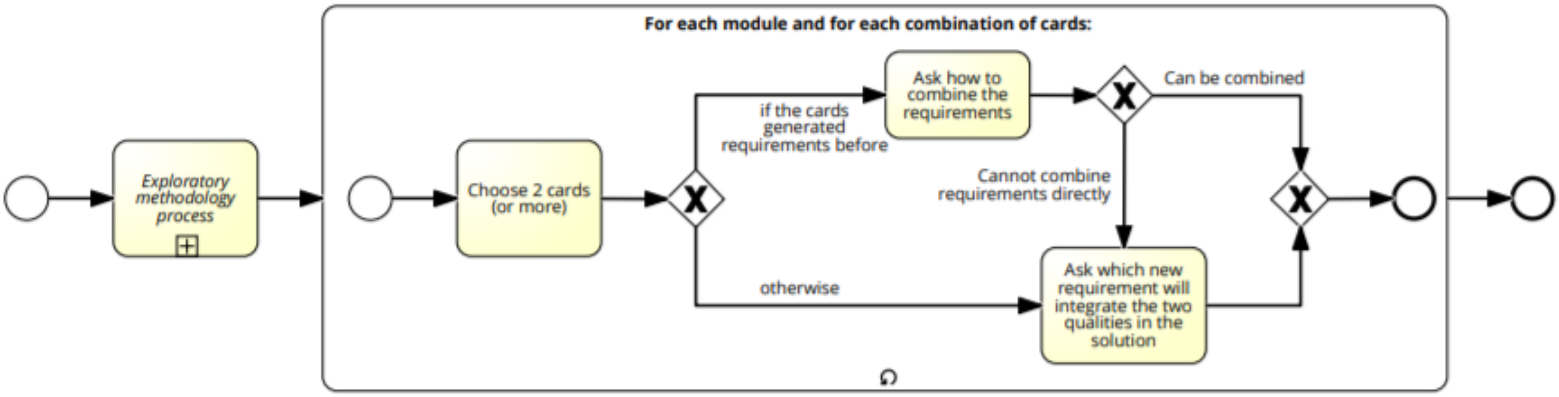

Figure 4.9: *Combinatorial methodology process*

Methodology for transformational creativity

The Figure 4.10 exposes a BPMN to show the flow of the current methodology (see Appendix B.4 for a full page version).

1. For the desired modules, the constraints need to be identified, listed and sorted by importance. The more important is a constraint, the less likely it can be modified or deleted.
2. Then, for the less important constraints, the practitioner and the stakeholders should come up with a modification of the constraint or even with the complete deletion of the constraint.
3. A CT card must then be used with the constraint in order to identify new requirements that are now possible due to the modification of the constraint.
   (a) If the modification (or the deletion) of the constraint is viable within the project, the newly generated requirements are validated.

(b) If not, the stakeholders must be asked how to adapt the requirement to fit the initial constraint.

4. The steps (2) and (3) must be repeated for each desired constraints.

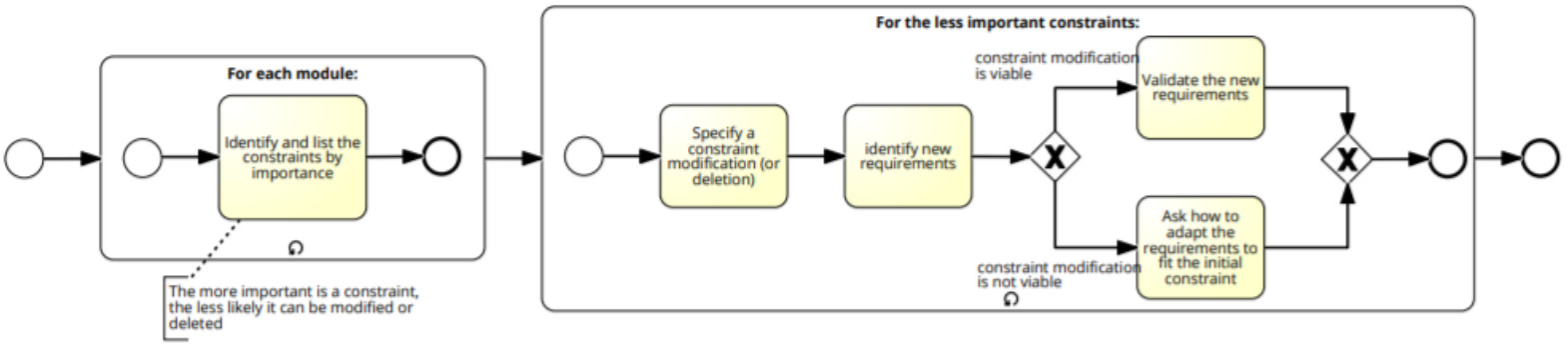

Figure 4.10: *Transformational methodology process*

After elicitation phase

This part comes right after the elicitation phase. The Figure 4.11 exposes a BPMN to show the flow of the current process.

1. The RE practitioner must ask an overall feedback about the tool. It allows the practitioner to better adapt the tool if the stakeholders use it again later in the project.

2. The RE practitioner must ask a feedback about the card names to assess the usefulness of the qualities. If another iteration of the elicitation phase is done, the practitioner will be able to focus on the most important qualities if it is necessary.

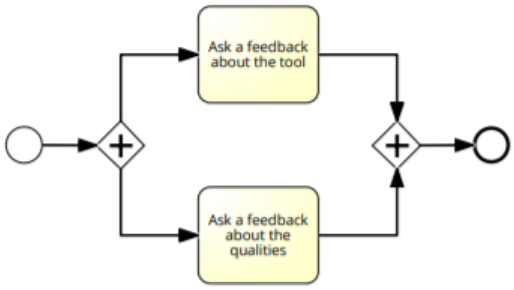

Figure 4.11: *After elicitation process*

General overview

All in all, we strongly advice to do the *Exploratory methodology process* in a first time for every project. Then, it is up to the RE practitioner to do the *Combinatorial methodology process*, the *Transformational methodology process*, both or none of them. Doing the *Exploratory methodology process* in a first place allows to be complete and to surface all the requirements.

The Figure 4.12 exposes a BPMN to show the flow of the whole methodology that needs to be applied in every project (see Appendix B.5 for a full page version). It depicts how to combine the three specific methodologies within the same RE project.

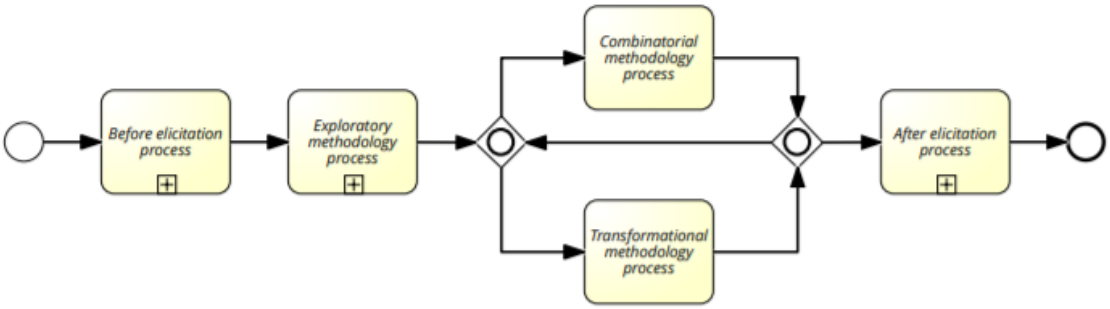

Figure 4.12: General methodology

Remarks

1. It is important to denote that every RE project is specific to its own environment and to the way the practitioner leads the RE process. This is the reason why the methodology provides general support leaving enough space the use of the tool if it is necessary.
2. We strongly advice to use a physical version (in multiple copies if the number of stakeholders is too high) of the Creativity Triggers instead of a digital version. Indeed, we believe that a physical version and the ability to touch the cards is more striking than a digital version.

Chapter 5

Validating Creativity Triggers

This chapter intends to evaluate the effectiveness and the usefulness of the Creativity Triggers in a context of Requirements Engineering elicitation. The main objective is to show that the tool is an effective support to trigger the creativity of the user. We proceed to the evaluation with a business analyst on a real-world project: the requirements elicitation of a bank extranet. The idea was to review the requirements with the tool to see if new creative requirements are generated. We present the methodology that we followed in section 5.1 Methodology while we depict the result of the validation in section 5.2 Results.

5.1 Methodology

To assess the ability of CT for generating both creative and competitive requirements, we proceeded in three steps. As a starting point, we had a requirements document previously done by the business analyst. We assumed that the document contained all the basic requirements that every bank extranet must at least have. We divided the project into several modules corresponding to different extranet functionalities to facilitate the elicitation, namely:

1. Connection and navigation
2. Personal dashboard and warnings
3. Accounts viewings
4. Transactions
5. Personal banking identity and statements of account

For *step 1* and *step 2*, we did the elicitation of requirements through all these modules. When it was necessary we had the opportunity to navigate through the mock-up website of the extranet.

5.1.1 Step 1: elicitation without Creativity Triggers

To begin the validation, we reviewed the overview of the project with the business analyst. The point was to understand the objectives, the challenges, the risks, the actors and the functional and non-functional constraints of the project. It was necessary since we were not familiar with the project. Then we revised the document, on the first hand, to better master the various modules and, on the second hand, to effectively confirm that the requirements document was

complete according to the analyst. Concretely, we led a discussion around each module and we wrote down each new requirement.

5.1.2 Step 2: elicitation using Creativity Triggers

The second step consisted in doing the elicitation again but now by using the Creativity Triggers. We led the same discussions than step 1 with one or several cards of the tool for each module. During this step, we experienced the proposed methodologies of section 4.2.2 Creativity Triggers methodology. Table 5.1 depicts which cards were used and which methodology we applied for each module. We decided to start with the exploratory methodology for each module. When the card did not produce enough requirements for a specific module, we tried the combinatorial methodology. Afterwards, if we felt that a constraint was limiting the creativity, we also used the transformational one.

Modules	CT cards	Methodology
3	Refined, Accessibility, Attractive,	Exploratory
4	Comfort, Cohesion, Novelty	Exploratory
2	Amusing, Humerous, Surprising, Conception, Ingenious	Exploratory, combinatorial and transformational
5	Independence, Up-to-date	Exploratory and combinatorial
1	Powerful, Smallness	Exploratory and combinatorial
Overall project	Eco-friendly, Price, Portable, Technology	Exploratory and transformational

Table 5.1: Cards used for each module

5.1.3 Step 3: comparison of the results

During step 3, we compared the results of the first two steps to evaluate the creativity and the competitiveness of the requirements generated with the Creativity Triggers. This step took place one week after step 2 to be sufficiently removed from the project. In practice, we collected 47 new requirements during the first two steps. We mixed the requirements from step 1 and step 2, we presented them to the business analyst and we asked him to point out the most creative or competitive requirements without knowing from which step the requirements came from. Moreover, the business analyst was asked to list the 3 best requirements that would distinguish the most the extranet from the competition. Afterwards, we led some discussions with the analyst to get his feedback about the tool and the support it gave.

5.2 Results

After the validation phase, we have a lot of insights and feedback to assess the tool. This assessment can be done what regards the quantity and the quality of the requirements created with the tool. By quality, we mean the creative and competitive essence of the requirements.

First of all, Table 5.2 presents the number of new requirements that were elicited during each step. This number corresponds to the requirements discovered during the validation phase that were not in the initial document. In a general way, we can assert that the tool helped to generate more requirements. For almost every module, the business analyst uncovered more

requirements with the CT than without. The idea is supported by the business analyst himself. After he discovered the first requirements with the tool, he mentioned that *"when we start generating ideas, we then cannot stop"*.

	Step 1	**Step 2**
Module 1	1	2
Module 2	4	5
Module 3	3	11
Module 4	6	9
Module 5	3	2
Overall project	0	3

Table 5.2: Number of new requirements

In general, both step 1 and step 2 produced new requirements. However, we noticed that the tool allowed to explore a wider scope and to reach a lot more creative requirements. For instance, these requirements come from step 2 and are recognized as creative by the business analyst:

- Sign a bank transfer by text message or the mobile application.
- Integrate machine learning to present news that fit the user's interests.
- Use an adaptive cloud to become more environmentally friendly.

During the third step, the business analyst identified, from the 47 new requirements, 18 requirements as the most creative and competitive ones. It was interesting to see that 11 of the 18 requirements were generated during step 2. The business analyst presented the 3 best requirements that would make him buy the system if he was a customer. These are the following:

1. An automatic notification that warns the user when a deadline loan is coming and that there is not enough money on the account to pay it. It aims to avoid paying a late fee.
2. A button that switches from your private account to your professional one.
3. A recommendation regarding bank investments. It would present the target that will be reached if the user follows a particular investment plan.

In general, the feedback of the analyst was positive. The tool was appreciated for its ability to guide the discussions and to open some avenues for further thinking. The analyst compared the tool with the brainstorming technique. During past brainstorming, he said that stakeholders sometimes do not have any idea and they are stuck without generating ideas. This downside seems to be overcome with the tool. Indeed, the tool helps to set the direction of thinking. Moreover, the tool was valued for its easy usage and for the fact that it does not require any prerequisites.

Regarding the cards, it was interesting to see that one single card sometimes started the exploration of different ideas. For instance, the card *Accessibility* was considered in two senses. First, it led to make the system accessible for colour blind and hard of hearing people. Then, the business analyst understood the quality *Accessibility* as making the system accessible everywhere through the use of mobile devices or the use of offline mode. The conclusion is that the cards are not too specific.

To conclude the validation, we asked the analyst to list the advantages and disadvantages of the tool. The advantages are:

- The easiness of the tool. There is no barrier with the use and the implementation is straightforward.
- The tool generates ideas with a great scope maximising the number of topics that are reviewed during elicitation.
- The methodology is flexible and the tool may even be used without leader.
- In opposite to brainstorming, the effectiveness of the tool depends less on the people by giving concrete support and direction.

The disadvantages are:

- As it generates a lot of ideas, the exploration of each idea is more general. Some requirements need further deepening. It can be interesting to couple the CT with other techniques.
- The tool creates a lot of ideas. It is then necessary to sort the ideas but the tool does not give support for that.
- The outcome of the tool is less structured.

Some of the downsides presented are out of the scope of the tool. The other one can lead to interesting improvements regarding the tool. All in all, the validation phase somehow confirmed the effectiveness of the tool. It contributed to more creative and competitive requirements. Its usage was straightforward. Even if the validation phase was done with one participant, the tool gave promising insights for a group usage. The ability of the tool to focus the discussion would be even more valuable if the number of stakeholders increases.

Chapter 6

Discussions

6.1 Limitations due to study design

As already discussed, our empirical study was a combination of an online questionnaire (to gather qualities) together with a real-world case study (to validate the effectiveness and the methodology of the tool). Just like any empirical work, our study is subject to some validity issues. Some are related to the design of our study (threats to *internal validity*) while others are related to the generalizability of our conclusions (threats to *external validity*). We discuss those two types of threats in the following subsections and give indications of how we tried to mitigate them.

Threats to internal validity An obvious threat to the internal validity is the *repeated testing*. It depicts that the answer to a question can be biased if the respondent has already been confronted to the question before. In our work, this threat can be identified along with our survey. Indeed, the respondent can submit the survey multiple times and he can also submit after consulting the results of other respondent. However, as explained in section 4.1.1 Survey, we believe that the threat is not relevant in our case due to the design of our data manipulation. We wanted to see which quality is associated to innovation by the respondent. In the case that the respondent submits multiple times or submits the qualities of other respondents, it does not biased the fact that he considers the qualities as innovative. The threat would only have been relevant if we would have used the occurrence of the quality to assess its importance which was not our case.

The second threat is the *experimental mortality*. It appears when some respondents (or answers) are removed from the study throughout the study. It is relevant in our case since we reduced the gathered qualities to a list of unique qualities. As a consequence, some answers from the respondents did not appear later on in the study. As a matter of fact, we did not measure how many times a quality was quoted as we worked with a list of unique qualities. The occurrence of qualities would translate their importance. It would make sense that the most quoted qualities are more important and that they would have a Creativity Trigger card with more probability. Even if it is relevant, the mechanism can be implemented if and only if the *repeated testing* threat is solved.

Threats to external validity To enhance the external validity as much as possible, our objective was to increase the amount of data compared to what is done in [**1**]. Moreover, our sample was not restricted to people with specific characteristics. So we believe that it is the

most heterogeneous. To monitor this heterogeneity and to control the external validity, we collected some pieces of information about the demographics of our sample. Indeed, if our sample is too small or too specific, the external validity is threatened. Among the collected data, we identified some variables on which the sample could be too specific, namely the gender, the age, the country of living and the experience toward innovation. We constructed some plots over these variables to verify the heterogeneity of the distribution.

As depicted in Fig. 6.1, the distribution of the gender is well allocated.

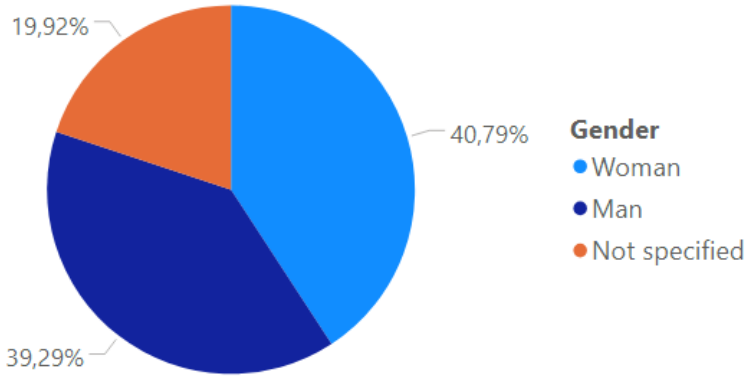

Figure 6.1: Gender distribution of the sample

Fig. 6.2 depicts that the most predominant age groups are *"20 years old or less"* and *"21 - 30 years old"*. The two groups represent 68,61% of our sample. If the age is relevant with qualities linked to innovation, it would be a threat to the external validity.

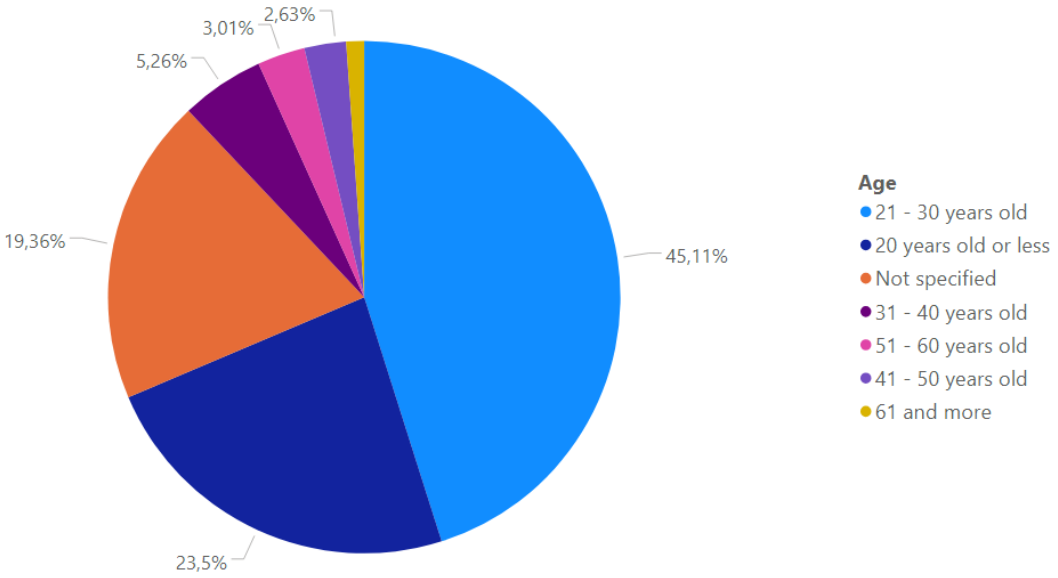

Figure 6.2: Age distribution of the sample

As depicted in Fig. 6.3, the most frequent countries are Belgium, France and United Kingdom. However, the data was collected across 17 distinct countries around the world. So we believe that it highly contributed to the heterogeneity of the sample.

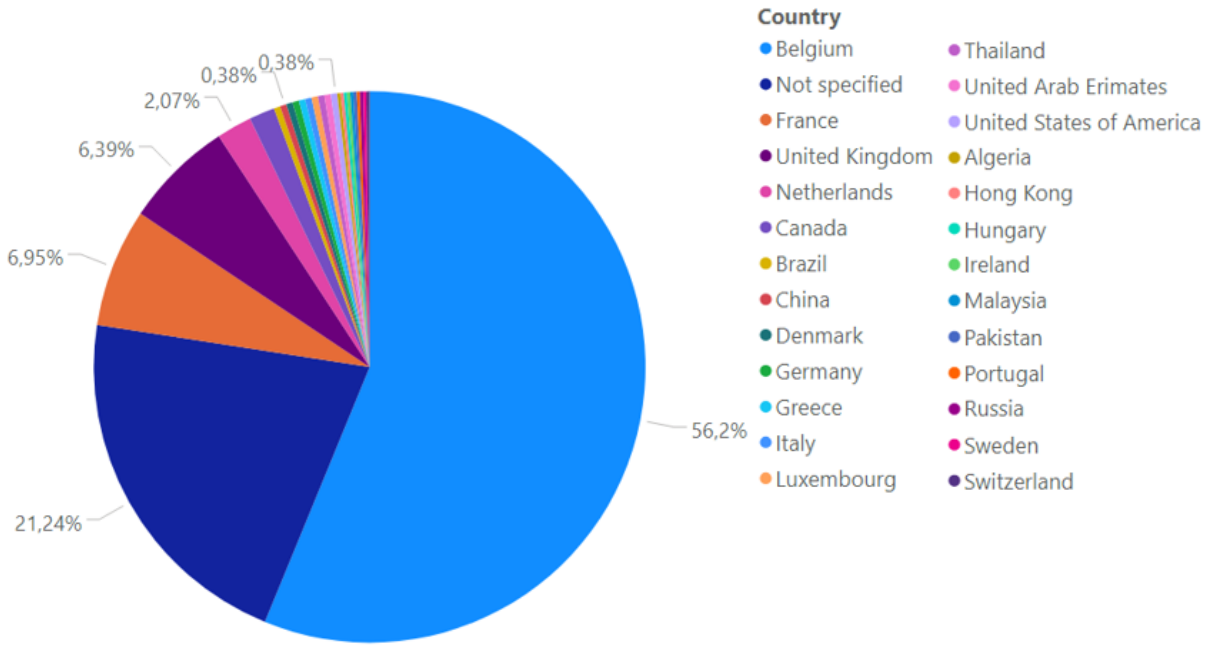

Figure 6.3: Country distribution of the sample

Fig. 6.4 shows the distribution of the experience of the sample regarding innovation. As we can see, the experience is quite well allocated among the various levels of experience even if the less frequent categories is *Strong experience*. The lack of strong experienced respondents does not seems to be a threat since we believe that experienced people would have given less intuitive answers.

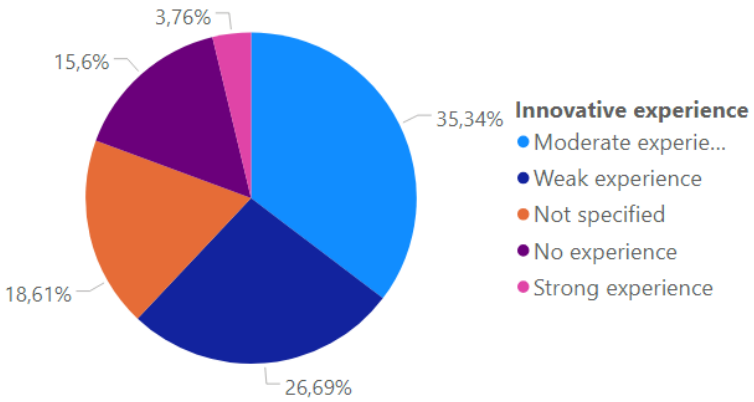

Figure 6.4: Experience of the sample toward innovation

Even if our sample seems well enough heterogeneous, the most obvious way to enhance the external validity of our work is to further increase this heterogeneity. We mainly mean to increase the number of respondents, the diversity of ages and the diversity of countries.

6.2 Limitations due to data treatment

During our data manipulations, we identified two limitations that may be overtaken. In the subsequent paragraphs we present these limitations.

Clustering technique Regarding the clustering we applied, we think that an improved version can be presented. We investigated techniques like *spectral clustering* or *KMeans clustering*. We believe that such techniques which are more formal than the one we used can produce interesting outcomes. At least, further investigations should take place. The only problem was to determine the number of clusters. As the amount of data is big, this number cannot be determined by hand. Some visual supports need to be implemented in order to determine the right number of clusters. We used *Multi Dimensional Scaling* (MDS) from SKlearn[1] to have a visual representation of our qualities. In such representation, two similar qualities have to be physically close while two dissimilar qualities have to be drawn as far as possible. We tried to use MDS and we effectively created a visual representation from our *313 x 313* similarity matrix. The problem was the following. Two qualities that were very dissimilar but having the same behaviour against the other 312 qualities were drawn very close with MDS. In other words, if two qualities were dissimilar with the Wpath metric, but having the same similarity with the other qualities, they were considered as having a similar profile and thus MDS saw them as close. The principle would be true if and only if we work with the entire dictionary which was not our case. This is the reason why we implemented our custom clustering. The latter better fits the particular context of our work regarding the similarity metric. Nevertheless, we plan to further investigate this limitation to maybe propose another clustering technique.

Clusters of one quality During our manipulations, we worked with a list of unique qualities. To create our Creativity Triggers cards, we then only considered clusters of more than one quality to avoid irrelevant qualities. We assumed that if a quality has similar words in the list, it confirms its relevance. In this particular case, if a quality does not have any similar words in the list of qualities, it will result in a cluster of one quality and it will not be considered for the CT cards creation. However, the fact that a quality does not have any synonym does not always mean that the quality is not relevant or even important for our case. It would be interesting to investigate all clusters of one quality to assess their relevance. Nevertheless, to fulfil this task, we have to find a systematic way to assess the relevance of a quality regarding innovation.

6.3 Future researches

During our work, we identified some aspects of the Creativity Triggers that may be interesting to explore. We did not investigate them since there were out of our scope. However, if they are proven relevant in the future, they can be opportunities to lead further researches and to somehow enhance the Creativity Triggers. In what follows, we present these future researches.

[1] A python library that allows clustering in Python.

6.3.1 How to choose the relevant CT cards

During the validation of the tool in chapter 5 Validating Creativity Triggers, we subjectively choose which cards to use for the validation project. However, there is a clear opportunity to design a tool or a methodology which would help the RE practitioner to determine which CT cards are the most relevant for his own project. Indeed in chapter 2.2 Creativity (particularly in section 2.2.1 Definition), we have seen that the creativity must be defined within each RE project. For that purpose, Mahaux et al. present a framework in [**24**] that leads the RE practitioners defining the creativity. We see a clear opportunity to adapt the framework of [**24**] to the Creativity Triggers. Following the ambition, the result of the adapted framework would be two-fold: the RE practitioners will have the creativity defined within his own project (as proposed in [**24**]), and moreover, based on that definition, he will get a methodology to chose the most relevant cards for his project.

6.3.2 Assessment of the qualities

Each card of the CT represents one quality. It would be very interesting to have a tool that assesses the impact of each quality within a particular project. The benefit would be two-fold. First of all, it would allow to determine which card of the tool is the most useful. Secondly, if we evaluate these qualities on a lot of projects from several domains, it would give us some insights on the impact of each card within specific domains. In fine, we would be able to identify a subset of cards that seems the most relevant for a particular application domain. For instance, if the project takes place in the marketing sector, we would be able to propose the subset of cards that is the most striking. In parallel with the section 6.3.1 How to choose the relevant CT cards, it would also support the choice of the cards for a project.

6.3.3 Online platform

In [**1**], they plan to design an online platform to share around the Creativity Triggers. This platform is not yet designed but the ambition is still relevant so we also plan to do it. The goals of the platform would be multiple. First of all, it would give access to the tool and to the works that are already done around the Creativity Triggers. Secondly, it would be a means to gather experiences around the tool and to effectively evaluate it with greater scope. Finally, the platform would be a meeting point to exchange around the incorporation of Creativity in the Requirement Engineering; an aspect that is recognised by authors as more and more crucial.

6.4 Conclusion

In this work, our objective was to lead an empirical study as a way to further improve, extend and more systematically validate a set of existing Creativity Triggers presented in [**1**]. To do so, we proceeded in 2 major parts: the collection of data through online questionnaire and the data manipulation with a semantic network, namely Wordnet. With the survey, the ambition was to collect more data to increase the representativeness and the completeness of the tool. Regarding the data treatment, we used semantic tools to better design the revised cards. In the end, we designed 22 enhanced CT. They come with a concrete methodology that guides the user through the use of the tool.

Moreover, we reviewed the literature to emphasize the importance of creativity in the engineering field and to prove that some tools of techniques must support the RE practitioner to incorporate creativity into his projects. Consequently, some concurrent tools and techniques

were presented to demonstrate how the CT differ from each other. Generally speaking, the CT tool presents several advantages:

1. It is a lightweight tool that gives concrete and physical support.
2. It is specific enough to target several aspects of creativity but general enough to be used no matter the type of solution (service or product) of interest.
3. Its implementation is quite simple and does not require a lot of time, resources and prerequisites.
4. It allows integrating the three type of creativity within a RE project.

Finally, the validation aimed to assess the effectiveness of the tool. The CT revealed to provide great support to the stakeholders. The cards effectively triggered some discussions that ultimately resulted in new creative requirements. We pointed out that depending on the RE project, some cards revealed to be easier to use. Overall, the tool allowed to enhance the quantity and the quality of requirements regarding creativity.

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Appendices

Appendix A

Survey

A.1 Flyer

Figure A.1: Diffusion flyer

A.2 General survey flow

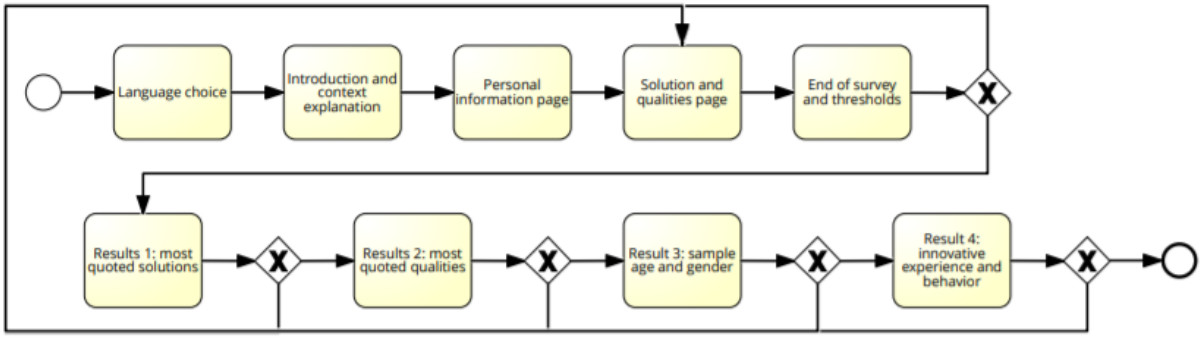


Figure A.2: Survey flow

A.3 Step 1 - Language choice

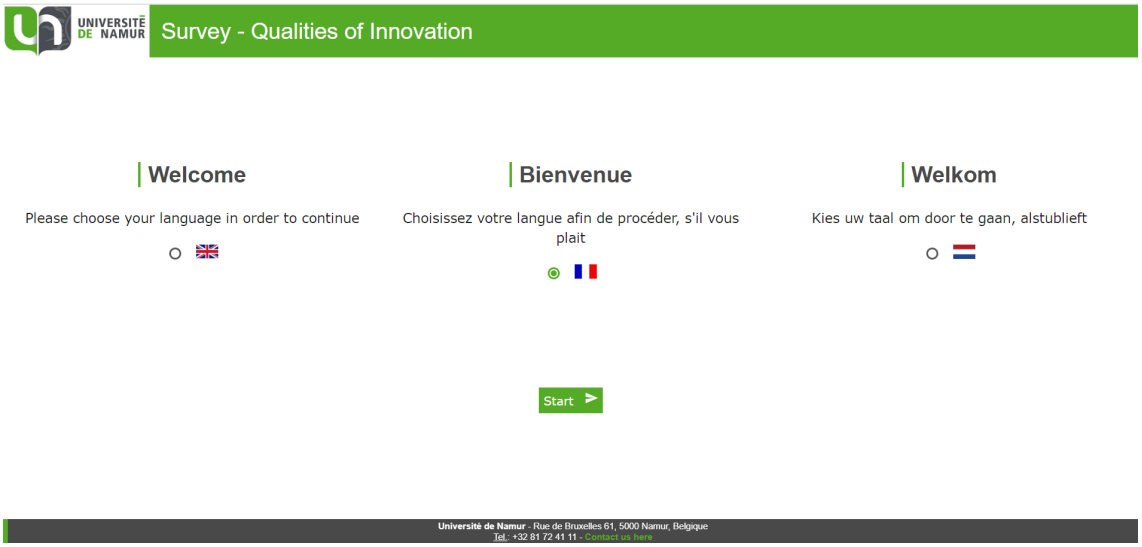


Figure A.3: Language choice

A.4 Step 2 - Introduction

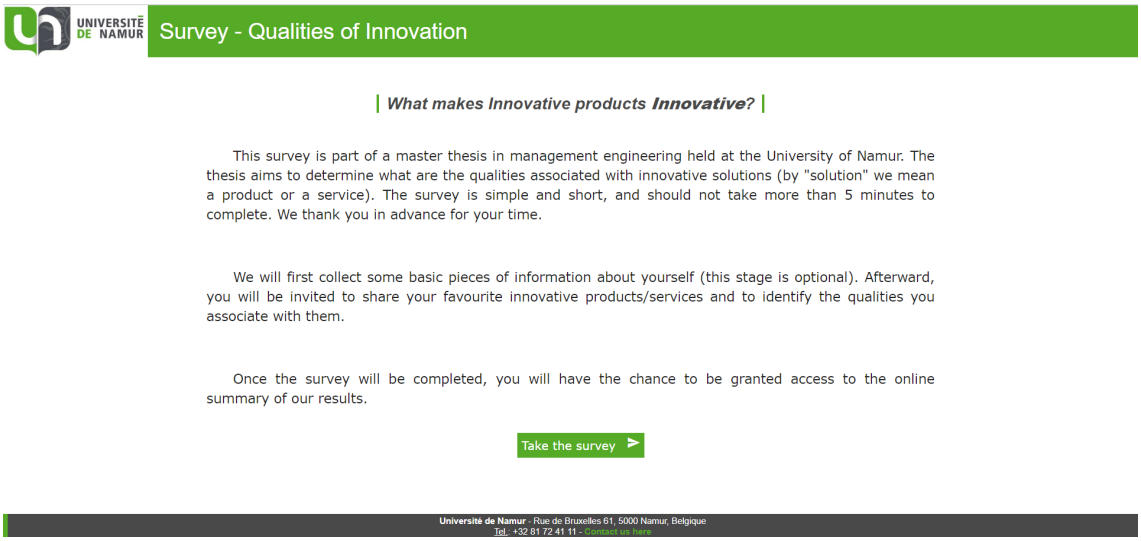


Figure A.4: Introduction

A.5 Step 3 - Personal pieces of information

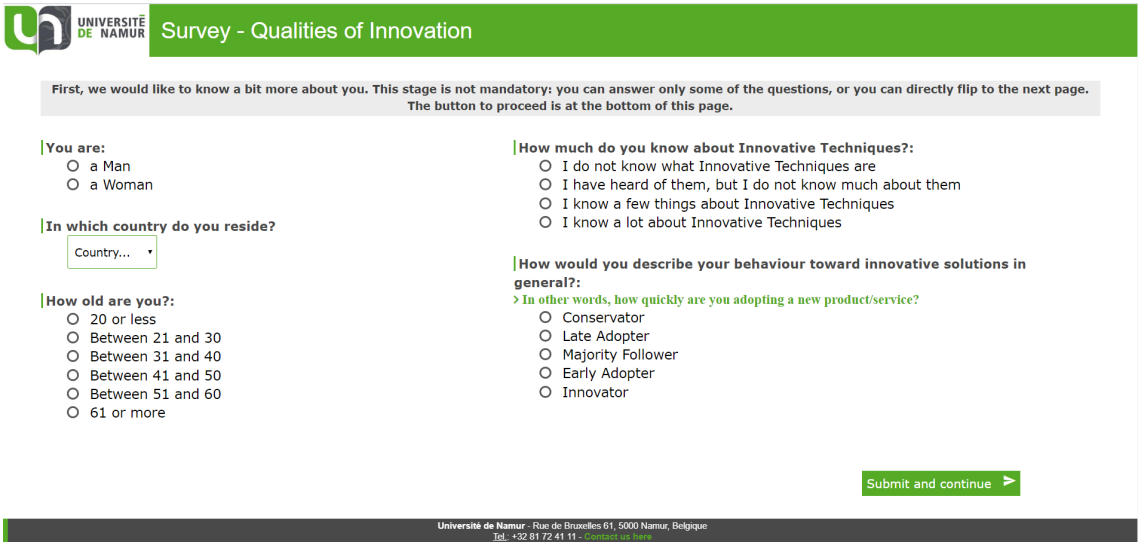


Figure A.5: Personal pieces of information

A.6 Step 4 - Solutions and qualities

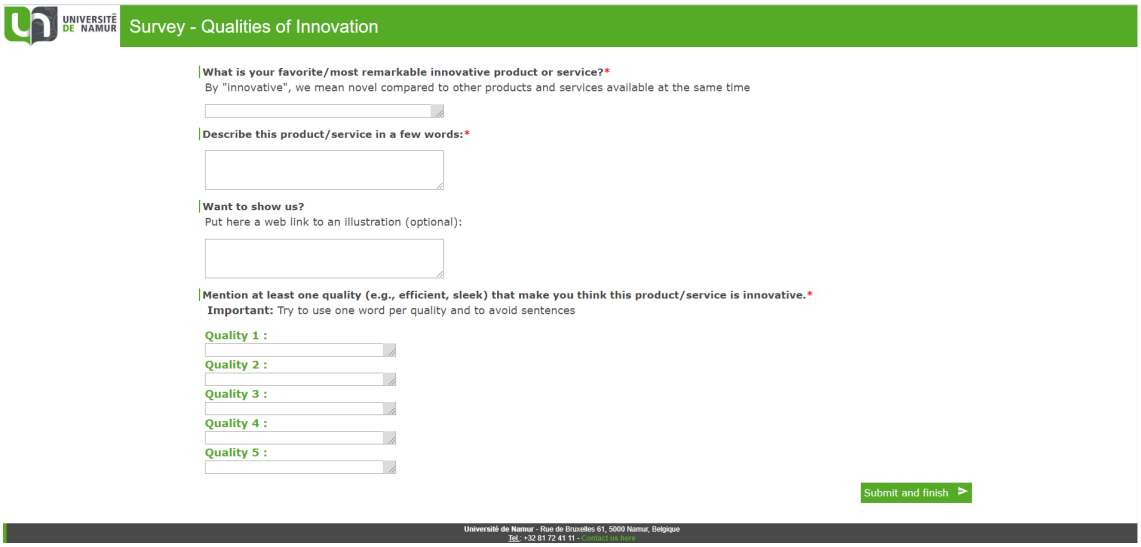


Figure A.6: Solutions and qualities

A.7 Step 5 - Survey end

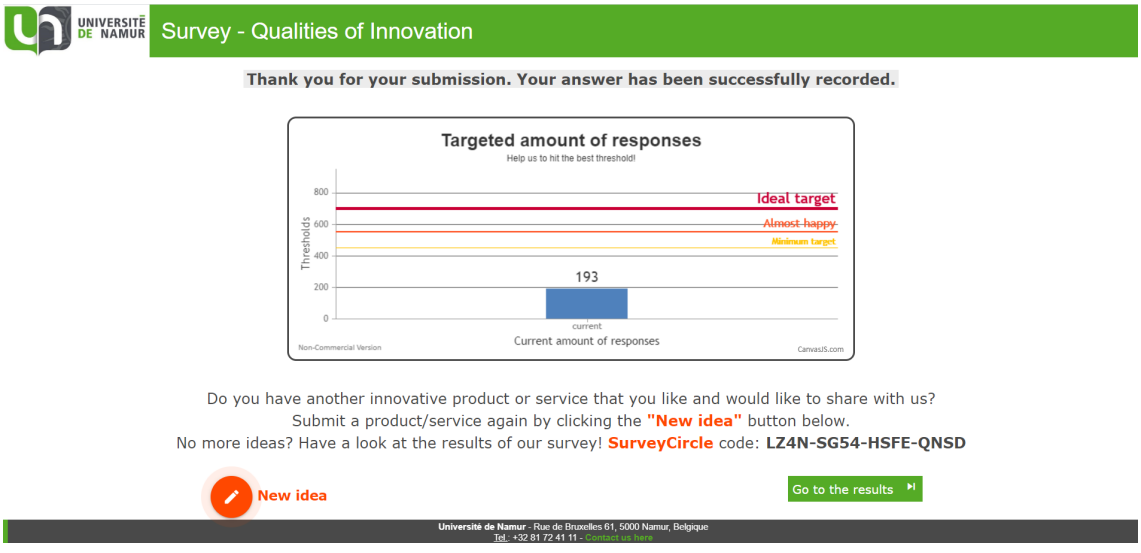


Figure A.7: Survey end

A.8 Step 6 - Survey results

A.8.1 Step 6.1 - Solutions

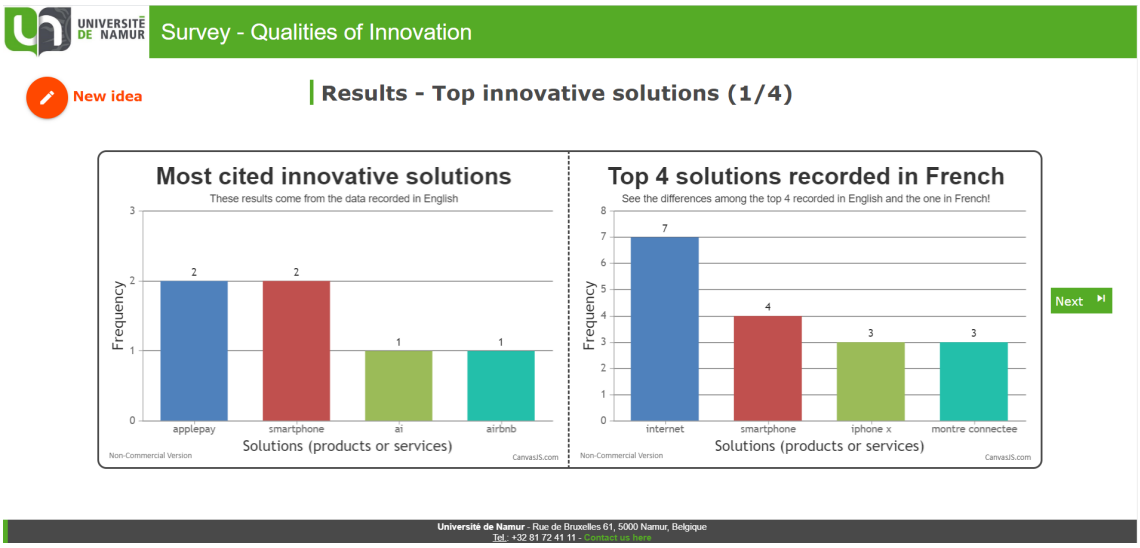


Figure A.8: Survey results: solutions

A.8.2 Step 6.2 - Qualities

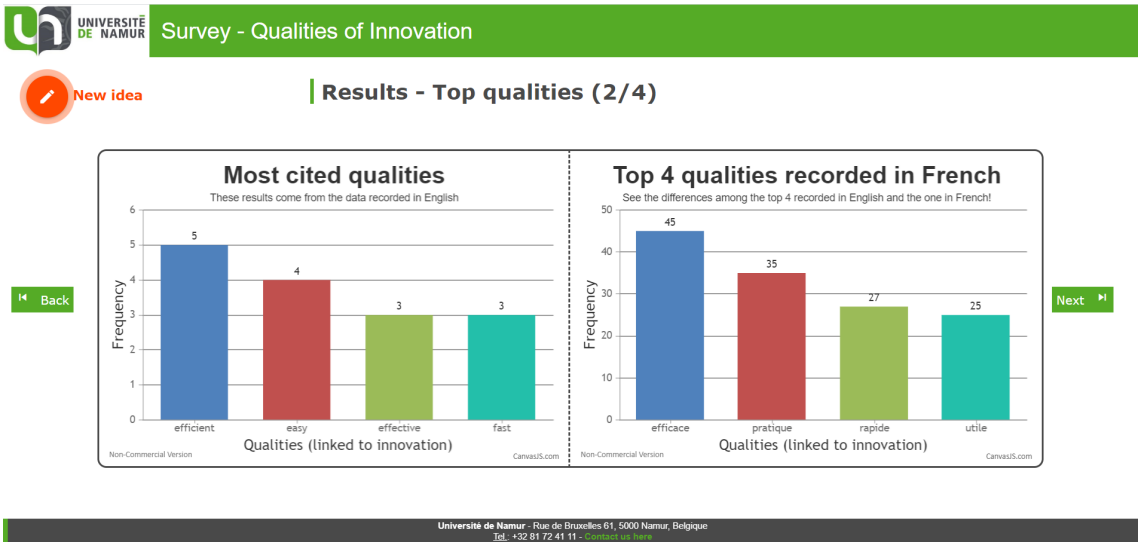


Figure A.9: Survey results: qualities

A.8.3 Step 6.2 - Sample gender and age

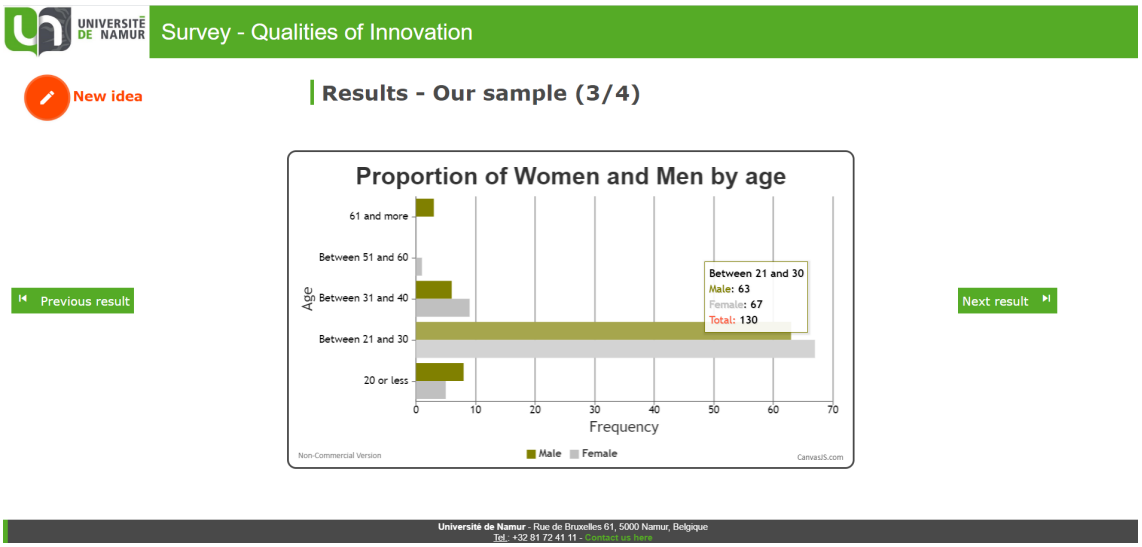


Figure A.10: Survey results: sample gender and age

A.8.4 Step 6.2 - Sample experience and behaviour

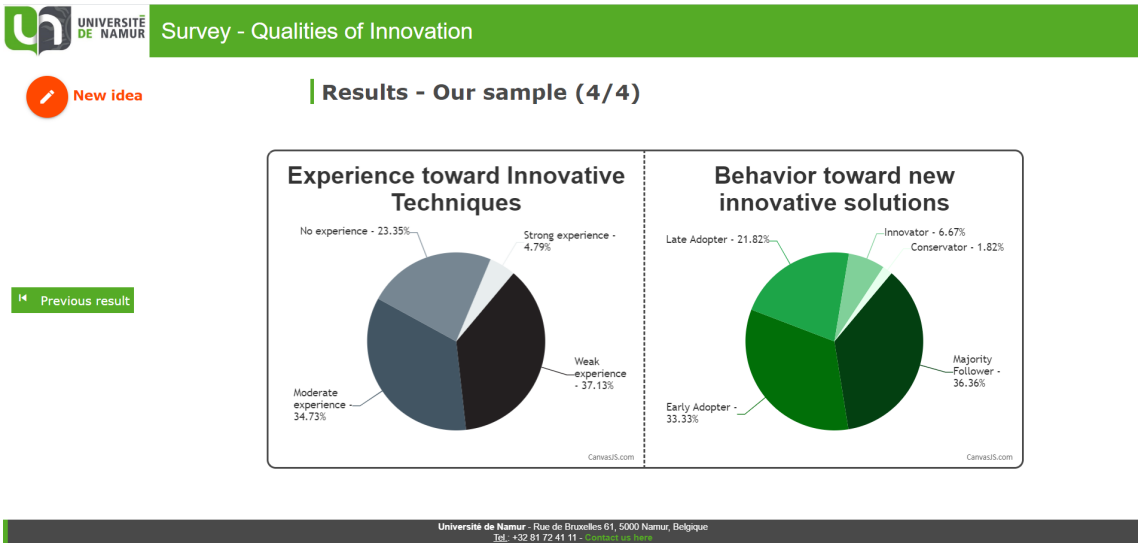
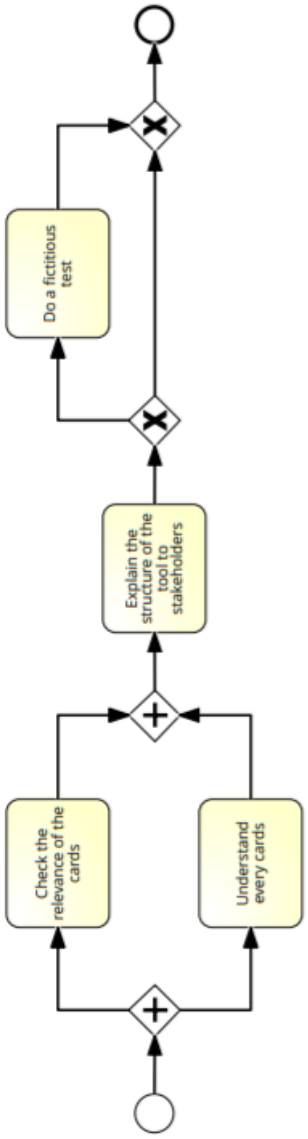


Figure A.11: Survey results: sample experience and behaviour

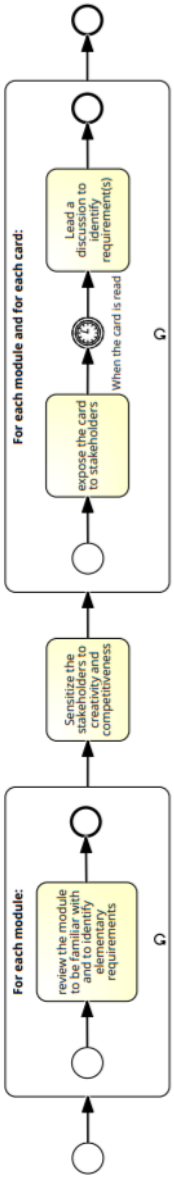
Appendix B

Creativity Triggers - Methodology of use

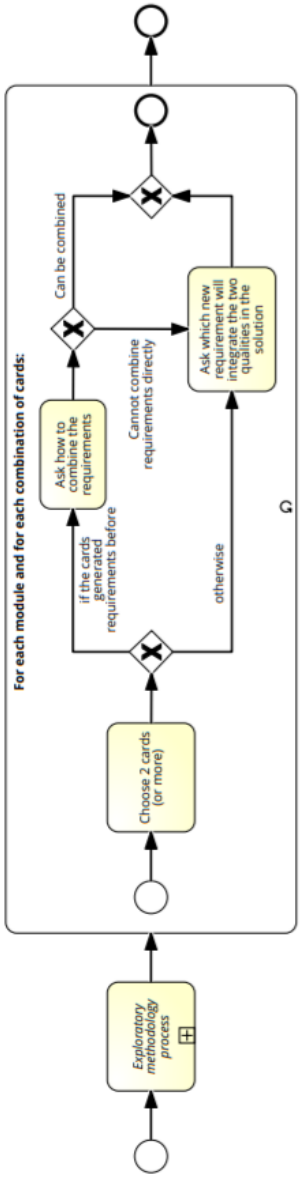
B.1 *Before elicitation process*



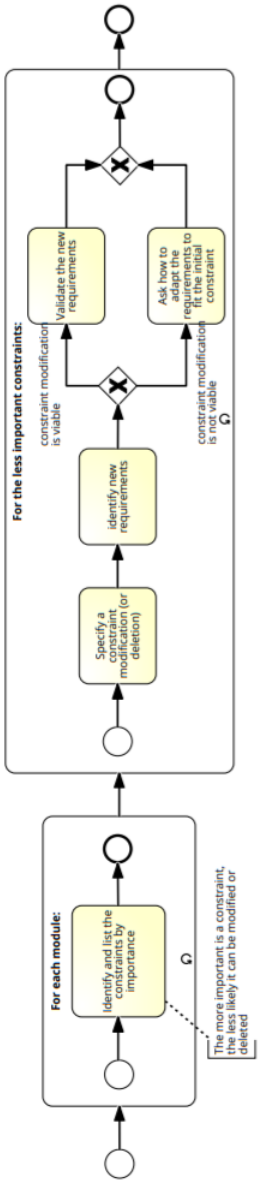
B.2 *Exploratory methodology process*



B.3 *Combinatorial methodology process*



B.4 *Transformational methodology process*



B.5 General methodology