UNIVERSIDADE FEDERAL DO PARANÁ

RICARDO CÉSAR RIBEIRO DOS SANTOS

A FRAMEWORK HARMONIZING THE MDA METHODOLOGY AND GAGNÉ'S MODEL OF INSTRUCTIONAL DESIGN FOR TRAINING IN LIVE LINE POWER SUBSTATION MAINTENANCE

CURITIBA

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Tese apresentada ao Programa de Pós-Graduação em Métodos Numéricos, no Setor de Tecnologia, na Universidade Federal do Paraná, como requisito parcial à obtenção do Título de Doutor em Métodos Numéricos..

Orientador: Prof Sergio Scheer, DSc
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To Clara and Carol

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“Look at me, still talking / When there’s science to do! / [...]
I’ve experiments to run / There is research to be done / [...]
I’m doing science and I’m / Still alive

(Portal 2 - Still Alive)

RESUMO

O treinamento profissional é um processo vital para empresas, uma vez que permite a especialização dos profissionais que executam as atividades relativas à manufatura de seus produtos ou da prestação de seus serviços. Ao se tratar de atividades de alto risco, porém, o treinamento assume importância vital, uma vez que falhas podem acarretar prejuízos financeiros, ferimentos ou até mesmo a perda de vidas. Para contribuir com o processo de treinamento, o grupo de pesquisa RV2 foi criado a fim de desenvolver um sistema de realidade virtual para auxiliar no treinamento de profissionais de manutenção de linhas de transmissão no contexto de subestações. O objetivo deste grupo é de não somente pesquisar o aspecto pedagógico da atividade de treinamento, como também desenvolver um sistema de realidade virtual em que os treinandos pudessem aprender atividades profissionais de maneira segura. Um dos objetivos do sistema é que os treinandos se sentissem motivados a interagir voluntariamente com o sistema virtual de maneira recorrente. Para que isso fosse possível, a teoria de jogos sérios foi incorporada ao desenvolvimento do sistema, a fim de aumentar a motivação e satisfação dos treinandos durante a interação com o sistema. O projeto também definiu que as teorias pedagógicas deveriam tomar parte da fundamentação teórica do sistema, o que acarretou na adoção da Teoria Instrucional de Gagné para o embasamento pedagógico. Porém, os referenciais teóricos precisavam ser conectados em uma base que possibilitasse o desenvolvimento e implantação do sistema. Assim, voltou-se para as teorias de game design para integrar o arcabouço teórico necessário. Inicialmente, o framework de projeto de jogos Modelo, Dinâmica e Estética foi utilizado de forma a guiar a análise dos aspectos de jogos sérios do sistema e posteriormente foi alinhado com o modelo instrucional de Gagné. Inicialmente, o processo de manutenção precisava ser modelado, evidenciando a necessidade de agrupar o conhecimento dos especialistas. A opinião dos treinandos também deveria ser ser levada em consideração, dada a necessidade de que estes interagissem de modo voluntário com o sistema. Para suprir essa demanda, a teoria de análise de discurso foi utilizada a fim de levantar como os treinandos se sentiam durante a execução dos exercícios de treinamento. O trabalho desenvolvido, assim, demonstra que o Modelo Instrucional de Gagné pode ser alinhado com o framework Modelo, Dinâmica e Estética para a produção de um framework para jogos sérios, em que tanto as teorias pedagógicas como as de Game Design são observadas. Finalmente, a experiência do treinando pode ser inferida utilizando entrevistas semi-estruturadas e os dados colhidos podem ser utilizados no desenvolvimento continuado do sistema virtual de aprendizagem.

Palavras-chaves: realidade virtual. eventos instrucionais de Gagné. jogos sérios.

ABSTRACT

Professional training is a vital process for companies, as it allows for the the specialization of workforce, enhancing the company's competitive stance and allowing to provide better service to the clients. In the context of high risk activities, such as live line maintenance, training assumes a pivotal stance as failures may result in the occurrence of infrastructure problems, harm to workers and in extreme cases, even loss of lives. To contribute to the training process, the RV2 research group was created aiming to develop a virtual reality system for substation live line training. Besides the pedagogical training, one of the project requirements was to create an environment in which the trainee would voluntarily engage in a recurrent manner. To allow for such interactions, the serious game theory was incorporated in the development of the virtual system, to enhance the motivation and satisfaction of the learners while interacting with the system. The project also defined that the pedagogical context should be observed during development, which prompted the research group to, out of numerous possibilities, choose Gagné's Instructional Theory as the pedagogical framework for the system. However, these two theoretical frameworks still needed to be connected in order to create a unified base for the deployment and continued development of the virtual learning system. Such technique would have to allow to incorporate the needed pedagogical premises in the game design theory and allow for any future additions to fall in line with the preexisting framework. To satisfy this need, research was conducted to verify how the elements could be connected in order to describe the whole system. Initially, Model, Dynamics, Aesthetics game design framework was chosen to guide the analysis of the serious game aspect of the system. This framework was subsequently aligned in a conceptual manner to the Instructional Design process and the Instructional Events described by Gagné. The process initially had to be modelled, which evidenced the need to create an interview capable of harvesting specialist knowledge. The trainees' experience also had to be asserted to be possible to analyze how the training environment fared in the opinion of the intended audience. To allow this data gathering, the discourse analysis theory was employed as a means to show how the trainees felt during the training exercises. The developed work allows for the conclusion that Gagné's Instructinal Method can be aligned with the Model Dynamics Aesthetics framework to produce a comprehensive serious game framework, in which pedagogical and game design theories are both observed. Meanwhile, the player experience can be asserted by semi-structured interviews and the data gathered can be used in the continued development of the virtual learning system.

Key-words: virtual reality. Gagné events of instruction. serious games.

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LIST OF ACRONYMS

ANEEL Agência Nacional de Energia Elétrica

AR Augmented Reality

COPEL Companhia Paranaense de Energia

HDMI High-Definition Multimedia Interface

HMD Head Mounted Display

LED Light Emitting Diode

MDA Mechanics Dynamics Aesthetics

RE Requirements Engineering

UEQ User Experience Questionnaire

USB Universal Serial Bus

UX User eXperience

UX User eXperience

VR Virtual Reality

SUMMARY

1 INTRODUCTION

Corporate training is a vital process for companies to keep their efficiency and competitiveness. In the case of high risk activities, the training process can assume an even more pivotal characteristic, as mistakes on these activities may incur in severe economic setbacks, property damage or even loss of lives.

To train electricians in live line maintenance, the electrical company in which this study was performed, adopts a progressive responsibility model, in which the trainees begin the learning process in a theoretical environment, focusing primarily in regulations and the theory of the activity procedure. After that stage has been finalized, the trainees, then, begin fieldwork with little responsibility, and as they get more experienced, are allowed to take part in more complex activities. After some time, they "graduate"and are considered fully trained professionals.

This learning approach has been chosen as the instructors do not possess the means to create a controlled environment that could simulate safely field conditions. This limitation appears primarily due to the high complexity of the adverse conditions observed in an electrical substation, not only due to the materials and their working conditions, but also due to weather and climatic conditions, wildlife interference and human possible flaws. The amount of variables to take into consideration is overwhelming.

Furthermore, the workers are aware of the inherent environmental complexity and hazard, creating daunting work conditions that discourages the experimentation process as a whole, even though the electricians themselves perform a considerable quantity of research and development for the technical advancement of the activities, either by implementing new tools or new procedures.

This approach reflects the fluid nature of the maintenance activity itself, that do not present an exhaustive set of rules and that relies on the professional experience and professional capacity of technicians to adapt techniques for specific scenarios and situations. Hence, the concrete situations, with all their associated complexities, have a key role in the definition of processes themselves.

As the professionals acquire more experience and become more familiar to the activities, other dangers arise, mostly due to them feeling more self-confident and forgetting some less usual procedures. These factors may lead to a state in which the electricians relax the safety procedures and get distracted, trusting muscle memory to perform some of the more frequent activities. This lapse on the cognitive process may lead to security flaws and create life-threatening conditions.

That is the reason for the need of a training methodology that takes into consideration the fluidity of the task and can allow for repeated training in which both basic and advanced procedures can be simulated, either by allowing for an instructor to create a specific training scenario or to allow for professionals to define their own parameters. In this manner, this process can be used as an instructional tool or as a means of recycling knowledge to seasoned professionals.

To address the need for a safe learning environment in which the electricians can train high risk procedures, specially the less usual ones, as many times as needed, a virtual environment was created. Virtual reality learning environments were created to aid the training of workers in hazardous conditions and have been applied to firefighting, as shown in (CHA et al., 2012), aviation safety, as detailed by (CHITTARO; BUTTUSSI, 2015) and has also been previously applied in a project from this same institution, (BURIOL; DE GEUS; SCHEER, 2012).

Virtual learning environments were created for training professionals that work in risk positions, such as commercial aircraft pilots, crane operators and firefighters. The retention rate of these virtual methods have, moreover, a high retention rate of the presented contents: around 90% versus 10% and 20% for traditional methods (RUIZ, 2015).

In this context, ANEEL (Brazilian Electricity Regulatory Agency), and COPEL, (Electrical Utility Company of the state of Paraná), sponsored the creation of a research group for developing and asserting the possibility of creating a virtual learning environment for electricians to perform live line procedures in a safe manner. Complementary to this focus, the final virtual environment should also observe modern pedagogical techniques, which were not present in the traditional training methods.

The RV2 project, developed by the OneReal Research Group, aimed at providing a means to supply a solution for that demand by creating a multi disciplinary group aiming the implementation of a virtual reality training system for electricians working in live line maintenance in substations. The group counted with active maintenance professionals who are involved in the training procedures and scholars from various areas of expertise, ranging from pedagogy to software engineering.

This work was developed in the context of such research group, aiming to contribute to the theory regarding the development of a virtual learning system and how to guarantee that it does fulfill its function to aid instructors in conveying practical experience to the trainees in a safe manner. For this purpose, the team defined both the medium through which the trainig content should be delivered and the pedagogical theory to allow for the effective content delivery.

By the aforementioned effectiveness reasons and increased hardware availability, virtual reality was chosen as the medium through which the trainees could access the virtual environment. As for the pedagogical framework, the RV2 team chose Gagné's Instructional Events, for it presented an algorithmic approach to the delivery of content that fit the procedure in a satisfactory manner, according to the pedagogical experts in the group.

1.1 MOTIVATION

The question if a learning system is effective or not is central to justify the development and implementation of such systems and their subsequent update and improvement. However, such mensuration is not trivially answered, as the concept of effectiveness is not completely objective. To aid the determination of such characteristics, the chosen concept of effectiveness was taken from (ISO, 2018), that defines the guidelines for User Experience in computer systems, and states that effectiveness is the measure in which a system allows for a user to accomplish a certain objective.

Moreover, the virtual learning systems should implement pedagogical methodologies to allow for the creation of an effective learning environment. This evidences the need of unifying the theories of game design and the pedagogical learning paradigms in a single theory and to allow for the creation of a learning system that communicates with the creation of a digital game.

In this kind of environment, it should be possible to tend the needs of learners and instructors alike while, respectively, consuming the educational content and creating learning scenarios. To allow for the maximization of the learning effectiveness, there should be a means of asserting the satisfaction to the needs of both user roles.

This was the matter that guided this research, how to use a game design framework to assert how learning environment designers should choose which elements to be prioritized during system updates and which new functions should be added during the development life cycle. This technique will not only maximize user satisfaction, but also allow for the system actors to be involved in the system development.

1.2 HYPOTHESIS

Taking into consideration the argumentation developed thus far, it is possible to notice that there is a gap that must be filled. More specifically, regarding how to collect information from users of a virtual learning environment, either learners or instructors and to instrumentalize this kind of information to allow for a better development life cycle, beneficial to the learning process. To answer this question, the following hypothesis was formulated:

It is possible to produce an instructional design inspired in the MDA framework capable of taking into consideration users feedback and use it to increase training quality and the trainees' motivation.

Taking into account the necessity to keep track of the user experiences, there is no satisfactory answer as how to assert which are the main features that can satisfy the instructional needs of the process. Thus, the value in creating an approach that allows for the trainees to share their experience and for it to be taken in consideration during the instructional software iterative development process of the medium through which the training experience is delivered.

1.3 RESEARCH QUESTIONS

To verify the validity of the enunciated hypothesis, the following research questions were created:

RQ01: How to elicit the instructional design needed for open-ended technical activities?

RQ02: How to connect Gagné's instructional design methodology and the MDA framework in a functional methodology?

RQ03: How to align the instructional requirements and learner's expectations in order to maximize motivation to learn?

RQ04: How to use learner's motivation to increase training effectiveness and quality?

This initial research question RQ01 aims to answer a need specific to the live line training environment, in which the maintenance procedure itself is fluid, partly based in the experience of the maintenance professionals, as during field procedures, it is not uncommon for the professionals to determine the process based on the concrete situation found on site. A virtual learning system that does not incorporate these characteristics would have its utility limited, hence the relevance of this research question.

Research question RQ02, was devised as a means to inquire as how the virtual learning system could convey the necessary knowledge in a satisfactory manner, as it had to initially be codified in the software development stage, as a functional requirement. However, non-functional requirements should be met as well, specially the one that stated that the trainees should be motivated to spontaneously interact with the system in a regular basis.

To meet this demand, the MDA framework, from the Game Design theory, was employed as a means to make the system as attractive as possible. However, to meet the pedagogical demands, a connection needed to be created between the instructional theories and the Game Design ones. This research question was enunciated to satisfy this need.

Finally, both research questions RQ03 and RQ04 were devised to incorporate the motivation and effectiveness factors in the process. In the UX theory, user motivation is directly related to how effective the system is, eliciting the need to assert how to incorporate this factor in the planning, development and assessment processes.

1.4 OBJECTIVES

From the previous research questions, the following main objective was obtained:

> To gather requirements and expectations, respectively, from instructors and trainees to create a virtual learning environment for training hazardous activities in the context of live line maintenance.

Then, this main objective was divided in three more specific objectives, which together would allow for the accomplishment of the main objective. Namely, those are:

O1: To harvest the experience and knowledge of specialists in live line maintenance

O2: To elicit the most important topics for professional training from live line workers

O3: Verify if the instructional design and the instructional outcome were aligned

O4: Create a comprehensive framework to analyze the processes of learner feedback and tutor knowledge harvesting

Objectives O1 and O2 have a straightforward purpose, as both of them are prerequisites to the implementation of the virtual learning environment. It is necessary to verify initially if the knowledge from the specialists was correctly codified in the training system and if the system successfully met trainees expectations.

For objective O2, an interview process was created specifically for the scope of this work, with the specific objective of gathering the desired information. The interview method was devised using discourse analysis and themes frequency counting.

Furthermore, objective O3 was devised to verify if the system executed the intended functions. In other words, to verify if the learner was exposed to the correct knowledge as intended by the instructors.

The previous objectives lead to objective O4, that utilizes the conclusions from the previous objectives to detail a theoretical framework which can guide the development of virtual reality serious games by including both instructional designer and trainee in the development process. This is possible by integrating the instructional design requirements with the trainee's motivations and expectations and enhancing the possibility for the users to feel that the virtual environment does provide a functionality that they expect.

1.5 DOCUMENT STRUCTURE

This document is organized as follows:

Chapter 1, the introduction, where the problem that motivates this work is detailed and contextualized. The problem is presented and discussed, as well as the description of the current training scenario.

Chapter 2, the theoretical basis, presents the theories used to develop the research. This chapter presents the theories and how they were instrumental to the development of this document, detailing well established theories and why they are useful to the work at hand.

Chapter 3, the bibliography review, presents the bibliography on the subject at hand. The process was divided in three sections, corresponding to the most modern research on each topic of the theoretical basis, aiming to present the evolution of the science and the limit of the techniques upon which the research is developed.

Chapter 4 details the hardware that can be used to display virtual reality content, the virtual reality concepts and the current limitations of the devices. This chapter also details how the user can interact with the virtual elements.

Chapter 5 details the methodology used to develop the virtual learning system and the techniques used in the development of the current research. This chapter shows how the techniques developed were used to gather information and allow for the research development.

Chapter 6 details the experiments conducted in order to acquire the data necessary to reach conclusions that answer the research questions. This chapter describes how the specialist's knowledge gathering and the trainee interview processes were conducted and the purpose of such procedure.

Chapter 7 discusses the results which were acquired from the application of the techniques, allowing for conclusions to be be reached and demonstrating the results that the technique can provide. This chapter allows for the identification of data trends and to interpret the results.

Finally, chapter 8 shows the conclusions which could be reached after the interpretation of data. This chapter shows the final conclusions and presents the findings of the technique applied.

1.6 ACKNOWLEDGEMENTS

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2 THEORETICAL BASIS

During the research process, both theoretical and practical assets had to be instrumentalized to allow for conclusions to be reached and to create a functional and practical framework. To evaluate which techniques should be studied to create a comprehensive theoretical toolkit, a survey was conducted for gathering the main theories covering the most important topics and authors in the fields of Game Design, Motivation, User Experience and Content Analysis.

The objective of this chapter is to describe the theories researched that create this work's backbone around which the content will be constructed. By no means it represents an exhaustive enumeration of available theories and models, as the process focused primarily in mapping the most widely accepted theories and frameworks (DE GEUS et al., 2020).

In section 2.1 the main theories regarding games and game design are presented. This section details how games create their own universe and how the players relate to the game artefacts and among themselves during the duration of the play sessions, how the play sessions are structured and how the rewards are distributed in the context of play.

Section 2.2 describes the theory created by Gagnè and how the instructional events should be structured. This theory defines how the instructional event should be planned and conducted, from the initial steps to the evaluation of the delivered content.

Finally, section 2.3 shows how the content analysis techniques can be applied to map themes and gather data from interviews. This technique was employed in order to allow for mapping the feeling reported by the trainees during the training sessions.

2.1 GAMES AND INSTRUCTIONAL DESIGN THEORY

Games are artifacts that are inherent to societies, as playful behavior is observed throughout the animal kingdom (HUIZINGA, 1949). Despite being present in even the earliest human cultures (HUIZINGA, 1949), there is no formal definition for this activity (SCHELL, 2008; FULLERTON, 2008). (HUIZINGA) (1949) defines the play behavior as a biological function and summarizes the theories which attempt to explain the presence of such biological characteristic (SANTOS; GEUS; MIQUELIN; SCHEER et al., 2017; SANTOS; GEUS; SCHEER et al., 2019).

> The numerous attempts to define the biological function of play show a striking variation. By some the origin and fundamentals of play have been

> described as a discharge of superabundant vital energy, by others as the satisfaction of some "imitative instinct", or again as simply a "need"for relaxation. According to one theory play constitutes a training of the young creature for the serious work that life will demand later on. According to another it serves as an exercise in restraint needful to the individual. Some find the principle of play in an innate urge to exercise a certain faculty, or in the desire to dominate or compete.Yet others regard it as an "abreaction" an outlet for harmful impulses, as the necessary restorer of energy wasted by one-sided activity, as "wish-fulfilment", as a fiction designed to keep up the feeling of personal value, etc. (HUIZINGA, 1949, p. 2)

It is necessary to notice how (HUIZINGA) (1949) places the act of play as a biological function, along with eating, drinking or breathing. This classification places the act of play in the basis of the pyramid of needs described by Maslow (MASLOW, 1943). The origins of this need is not explained, just conjectured to come from an era prior to civilization — just as the act of play from animals. Huizinga limits himself to say that people engage in playful activities by stating “This intensity of, and absorption in, play finds no explanation in biological analysis. Yet in this intensity, this absorption, this power of maddening, lies the very essence, the primordial quality of play.” (HUIZINGA, 1949, p. 2)

In order to address this issue, the Flow theory was developed and documented by Csikszentmihalyi in 1990 (CSIKSZENTMIHALYI, 1990) and further explained by the same author in 1997. The flow state is described as:

> First, the experience (of enjoyment) usually occurs when we confront tasks we have a chance of completing. Second, we must be able to concentrate on what we are doing. Third and fourth, the concentration is usually possible because the task undertaken has clear goals and provides immediate feedback. Fifth, one acts with a deep but effortless involvement that removes from awareness the worries and frustration of everyday life. Sixth, enjoyable experiences allow people to exercise a sense of control over their actions. Seventh, concern for the self disappears, yet paradoxically the sense of self emerges stronger after the flow experience is over. Finally, the sense of the duration of time is altered; hours pass by in minutes, and minutes can stretch out to seem like hours. The combination of all these elements causes a sense of deep enjoyment that is so rewarding people feel like expending a great deal of energy is worthwhile simply to be able to feel it. (CSIKSZENTMIHALYI, 1990, p. 49)

This quote describes the ideal situation, in which the person is fully invested in a given activity, such as climbing, running, playing music or playing a game. The concept of flow is tightly connected to the matter of attention, concentration and effort; it is a model to try and explain how to create an experience in which the player gets engaged just for the sake of getting engaged in such activity (SANTOS; GEUS; MIQUELIN; GODOI et al., 2018).

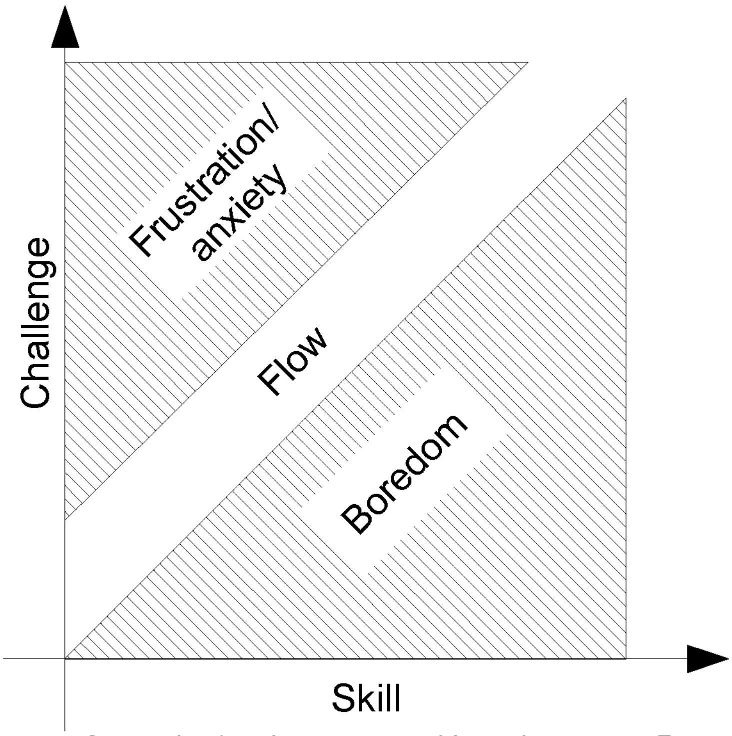

FIGURE 1 – Flow state, frustration/anxiety zone and boredom zone. Reproduced from (CSIKSZENTMIHALYI, 1990)

The flow state is intimately connected to challenge, which must be compatible to the proficiency of the player; a task which is too easy is boring, a task which is too difficult makes the subject anxious or frustrated, depending on how satisfactory the performance must necessarily be, as shown in figure 1.

When applied to games, this concept offers a good framework to track the progression of challenges based on the player proficiency. It must be noted that this is about the perceived challenge compared to the perceived skill rather than the actual skill and challenge. To keep a player interested and committed to the system, the challenge must progress along with the skill, in order to keep in the flow zone depicted in Figure 1.

Even though no formal definition of what a game is has been agreed on, some attempts were already made. Some were quite informal, as Sid Meyer's definition "a game is a series of interesting choices" (FULLERTON, 2008). In his book, (ROGERS, 2010) defines games as an activity in which at least one player takes part and that has both rules and a victory condition. The former states clearly what the player can and cannot do; the latter states when the game ends and how to determine a winner and a loser.

Some more definitions are cited in (SCHELL) (2008), who summarizes the definitions as a list of qualities of games, namely: 1. Are entered willfully; 2. Have goals; 3. Have conflict; 4. Have rules; 5. Can be won and lost; 6. Are interactive; 7. Have challenge; 8. Can create their own internal value; 9. Engage players; 10. Are closed, formal systems (SCHELL, 2008, p. 34). This list, though, is not comprehensive, as the author himself admits.

For didactic matters, in this thesis the definition of games adopted will simply be that games provide an experience for a player. This experience must be taken on both intellectual and sentimental level to be complete and engaging. By choosing that definition to game, it is possible to abstract the more concrete elememts of what a game is and focus on the creation and evaluation of a vehicule to deliver the desired experience; in the case of this work, the experience of performing a field job without actually going to the field.

No matter how elusive the formal definition of games may be, its components are well defined and can be described by the elemental tetrad initially described in (SCHELL, 2008) and further detailed in (GIBSON, 2015), and as described in the next section.

Serious games are defined as games that mean to convey a message rather than being merely an entertainment tool. These games may try to raise awareness to a specific social cause, may be used in advertisement and product placement, in education, in professional training, as a part of therapies, and many other fields. This does not mean that entertainment and fun are not considered, as these may be part of the experience intended by the designer, but it does mean that the message takes precedence over such matters.

The term serious game is believed to have first appeared in the works of Charles C. Abt, in the book Serious Games (SUSI; JOHANNESSON; BACKLUND, 2007), in which he states:

> Games may be played seriously or casually. We are concerned with 'Serious Games' in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should be not entertaining. (ABT, 1987, p.9)

In other words, serious games are games in which entertainment is not the main factor. It may implement some techniques to make the experience increasingly enjoyable or even fun, even though that is not the real purpose of the system. Recent works, however, such as (KHENISSI et al.) (2016), (OOSTENDORP; SPEK; LINSSEN) (2014), (JONES; WARREN) (2008) and (WEIZMAN) (2014) state that the entertainment factor enhances the learning outcome.

2.1.1 Magic Circle

During the game session, the players create a parallel world that may be as similar to the real world — the non-play world — as desired. It may have values and economic systems parallel from the real world, in which consequences of certain actions may be minimized or even nullified and roles may be created. All this effort is made in order to create an environment in which mistakes have little to no consequence that transcends the game world and invades the real world.

This limit may be of social, temporal or spacial dimensions, as described by Huizinga's magic circle of play (HUIZINGA, 1949) — even though in this context this theory only denoted the magic circle as the spacial constraint in which the activity is held, it is possible to notice in his work that these other limits are implicitly considered as well. In Huizinga's words:

> More striking even than the limitation as to time is the limitation as to space. All play moves and has its being within a play-ground marked off beforehand either materially or ideally, deliberately or as a matter of course. Just as there is no formal difference between play and ritual, so the "consecrated spot" cannot be formally distinguished from the play-ground. The area, the card-table, the magic circle, the temple, the stage, the screen, the tennis court, the court of justice, etc., are all in form and function play-grounds, i.e. forbidden spots, isolated, hedged, round, hallowed, within which special rules obtain. All are temporary worlds within the ordinary world, dedicated to the performance of an act apart. (HUIZINGA, 1949, p. 10)

In other words, the magic circle is an entity that impersonates all the restraints that separate the game world from the ordinary world. This is quite visible in sports, in which a court is defined and if its limits are breached, game sanctions are applied to the players. As an example, one could think of Sumo, in which the contestants are literally inside a circle, and to step out of it implies in a score penalty.

In fact, games which treat the magic circle in an unconventional manner have been developed and used in many manners, either in a serious context, or for entertainment purposes. These games use technology in the most diverse manners, such as using mobile devices, telephones, mail (electronic or otherwise), city buildings architecto-

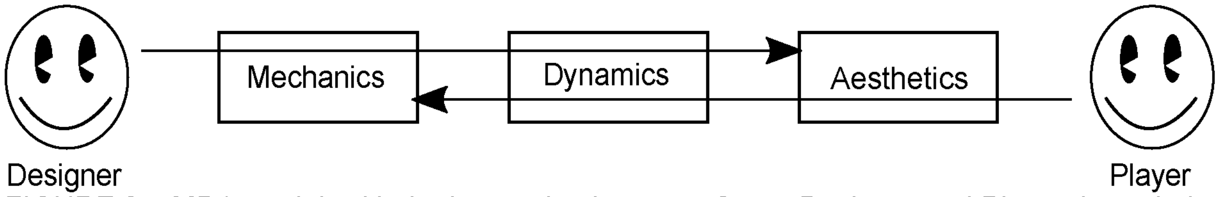

FIGURE 2 – MDA model, with the interaction between Game Designer and Player through the game elements. Source: (HUNICKE; LEBLANC; ZUBEK, 2004)

nic characteristics and many others (OPPERMANN; SLUSSAREFF, 2016; MONTOLA; STENROS; WAERN, 2009).

As technology advanced, games became more sophisticated and so did the definitions of magic circle. Currently, social networks play a decisive role on relationships, and the magic circle has expanded to encompass this new media and constraints (KONERT; SÖBKE; WENDEL, 2016).

2.1.2 MDA Framework

The MDA framework is frequently used to visualize and discuss the components of a game by separating the components in functional categories. This model was propose in (HUNICKE; LEBLANC; ZUBEK, 2004) and one of the standards in which game design and research occurs. The concept is illustrated in figure 2.

The MDA framework defines the game components in three categories according to their function (MUNHOZ, 2018):

- Mechanics: These components correspond to the rules of the game, or the rules of the business. We advocate that in the context of game-based learning, it should be possible to correspond them to the learning objectives, as enumerated in Gagné's Instructional Design event.
- Dynamics: This element is nothing more than the mechanical elements working. The interaction between the rules may create unforeseen behaviors, which can lead to new or undesired situations. In this layer, the trainee should be able to make mistakes and be evaluated.
- Aesthetics: This component appears when the player interacts with the game, or in the virtual learning environment in question, should appear when the learner interacts with the learning environment. This element corresponds to the feelings and sensations the player gets from interacting with the system. Even though the game designer can try to predict the player's reactions, this element is only created by the player during playtime.

Therefore, the MDA framework provide two entities that represent the lenses through which the designer and players view the game. In the context of the creation of learning environments, the elements of the model can be complemented with the addition of the learning elements.

As detailed in (HUNICKE; LEBLANC; ZUBEK, 2004), the layers of the MDA model that are closer to the system actors are the Mechanics and the Aesthetics, perceived more easily by the Designer and the Player, respectively. These components can be used as views of a game, in which the designer, or analyst, can use to interpret further a given artefact, as described in (HUNICKE; LEBLANC; ZUBEK, 2004):

> "What makes a game 'fun'? How do we know a specific type of fun when we see it? Talking about games and play is hard because we use is relatively limited.
>
> In describing the aesthetics of a game, we want to move away from words like 'fun' and 'gameplay' towards a more directed vocabulary."(HUNICKE; LEBLANC; ZUBEK, 2004, p. 2)

In a learning game, the learner must perceive not only the game interaction, gameplay and fun. In this context, the learner must perceive the educational aspect of the learning platform as well, along with the experience in the game itself.

It is possible to further define the game elements by using the Mechanics component, in which the designer defines how the game is played. In this element, the designer must create the rules and the limits that the players must follow during gameplay, or, as stated in (HUNICKE; LEBLANC; ZUBEK, 2004):

> "Mechanics are the various actions, behaviors and control mechanisms afforded to the player within a game context. Together with the game‘s content (levels, assets and so on) the mechanics support overall gameplay dynamics.
>
> For example, the mechanics of card games include shuffling, trick-taking and betting – from which dynamics like bluffing can emerge. The mechanics of shooters include weapons, ammunition and spawn points – which sometimes produce things like camping and sniping. The mechanics of golf include balls, clubs, sand traps and water hazards – which sometimes produce broken or drowned clubs."(HUNICKE; LEBLANC; ZUBEK, 2004, p. 4)

This means that the elements that define how the game is meant to be played correspond to the Mechanics layer, even though they may allow for emergent dynamics to appear. The game rules and elements must be defined and in a serious game, the game design must include the knowledge that must be presented to the learner as well as the game rules. So, the Mechanics layer must include the Instructional Design executed for the task at hand.

The final element of the MDA framework, the Dynamics, arises from the interaction between rules defined by game mechanics during gameplay. In this element, the game designers can define if a player is ready to be victorious or not and decide to penalize or to reward one or more players based on play conditions defined by the Mechanics. Such behavior creates an Aesthetic experience, either by introducing a positive/negative feedback system to keep players engaged or by announcing the winner and loser of a play session.

During a serious game, hence, if the rules of the game are defined in the instructional design stage, and is part of the Mechanics of a game, the learner should be evaluated according to the instructional design. In other words, this layer is where the evaluation of the learner should happen.

The discussion regarding evaluation is lengthy and outside the scope of this work. For more information regarding trainees evaluation, please refer to (FARIA, 2021).

2.2 GAGNÉ'S EVENTS OF INSTRUCTION

Robert M. Gagné studied the process of skill acquisition in the military context and based his theories in how learning changes the behavior of a certain individual; if after a given instruction process the learners have indeed changed the manner in which they perform some given action, it is a strong indicative that the learning process was successful.

2.2.1 Instructional Design

In order to create an instructional event as described by Gagné (GAGNE et al., 2004), the instructor must initially determine which will be the the knowledge transferred to the pupils. This initial procedure is referred to as the Instructional Design and is intended to allow the tutor to limit the scope of the course, organize prerequisites and course steps in a logical manner aiming the optimization of the instructional outcome – how much the pupil learns. As stated by Gagné:

> The planning of instruction in a systematic manner, with attention to the consistency and compatibility of technical knowledge at each stage of design, [...] uses various forms of information, data, and theoretical principles as input at each planning stage. Furthermore, the prospective outcomes of

> each stage are checked against whatever goals may have been adopted by those who manage the system as a whole. It is within this framework that we seek to apply what is known about the conditions of human learning to instructional design. The systematic planning of instruction to achieve learning is characterized by a process of stating goals, selecting or developing instructional interventions, and using feedback from learners to improve the instruction. (GAGNE et al., 2004, p. 12)

In this excerpt, it is possible to notice how Gagné made the instructional design process the centerpiece of his method, which provides the bases for both the instruction itself and its evaluation.

During the Instructional Design process, the instructor must determine which content will be transmitted to the pupils and organizes the prerequisites in an orderly manner (a flowchart is good practice, but other orderly manners may be used). In the end, the tutors come up with the testing and only then they are ready to prepare the other instructional events. In fact, Gagné believes that the design of the instruction is so fundamental, it communicates to the pupils why the instruction must take place. Or, as he describes:

> Precision in the definition of objectives meets the need for communication of the purposes of instruction and the need for evaluation of instruction. Objectives that are precisely defined provide a common technical basis for meeting both of these needs. The instructor wants to communicate the intended outcomes of instruction to students, teachers, and parents (when appropriate). Although these communications usually differ from one another in the ways they are stated, the instructor nevertheless wants all of them to express the same idea. This goal can be best achieved by having available a technically complete definition of the objective. (GAGNÉ; BRIGGS et al., 1992, pp. 125-126)

It is necessary to notice how it is assumed that the instructors have a deep understanding of the process as a whole in order to be able to dissect the knowledge in its prerequisite components, and to perform the same process on them recursively, until they feel a satisfactory level of granularity has been reached.

> Designing instruction for a course or topic must surely begin with an idea of the purpose of what is being designed. The greatest clarity in conception of the outcomes of instruction is achieved when human performances are described in the form of objectives. The question initially asked by the

> designer is not, "What will the students be studying?"but rather, "What will students be doing after they have learned?"This means that design begins with a consideration of the instructional objectives.(GAGNÉ; BRIGGS et al., 1992, p. 145)

While one may take for granted that in a course the instructor dominates the whole subject, in a virtual instruction system it is necessary for the whole team working on the implementation of such tool to share a conjoined view of the parts that make the whole instructional content. However, when roles are assigned throughout the team, not always the implementation team has access to the knowledge to be modelled, which could lead to the overlook of some important parts of the system.

To address this issue, the specialist's knowledge must be harnessed effectively, in order to allow the design team to create an effective learning environment to be used for professional training. For that matter, not only the instructional objectives must be clear, but the prerequisites must be accessible as well.

In the case of the RV2 virtual learning environment, the instructional events had to be inserted in the game design due to time constrains. This created a situation in which the instructional and game design had to be developed side-by-side.

In this case, the instructional design and the game design were developed in a synchronous manner, allowing for the instructional designer to have as much power as the game developer when creating the learning system. In this case, only one of the maintenance procedures was modelled after the creation of a procedure map for which the maintenance specialist was interviewed to gather the necessary information.

2.2.2 Gagnè's Instructional Events

The instructional model chosen by the RV2 project was based on Gagné's Nine Events of Instruction, in which the instructional event is divided in steps.

Robert M. Gagné studied the process of skill acquisition in the military context and based his theories in how learning changes the behavior of a certain individual; if after a given instruction process the learners have indeed changed the manner in which they perform the way they , it is a strong indicative that the learning process was successful.

In the work of (GAGNÉ; BRIGGS et al.) (1992), Gagné begins by exploring what should be learned in order to infer the how to teach such a competence. The list of what can be learned consists of five points, called the general classes. These are: 1. Intellectual skills; 2. Cognitive strategies; 3. Verbal information; 4 Attitudes; 5. Motor skills.

Intellectual skills are of key importance to academic learning and provide the best structural model for the instructional design phase. In this general class, individuals are given every means to respond to their environment through symbols that represent the actual objects of their own environment — may they be words, numbers, schematics, etc. Such symbols not only describe the actual physical objects, but they may describe the relationship among each other as well. The pupils must be able to combine these elements in order to communicate their experience, to remember and to think about their environment in a way in which problem solving capabilities are developed through the creation of rules and concepts derived form discriminations between world objects.

Regarded as a very specific intellectual skill, the cognitive strategies are control processes in which learners select the ways in which they learn, remember and think. In a manner, it is a problem solving skill, as it is focused on fixating and linking concepts to improve knowledge retention. Both the creation and application of such methods (like rehearsal strategies, elaboration strategies and organizing strategies) are of utter importance to a good cognitive process of the learner.

Verbal information is the ability to organize information into "bodies of meaningfully interconnected facts and generalizations." (GAGNÉ; BRIGGS et al., 1992, p. 79). This body of knowledge is passed on through the formal instruction — academic courses designed with the intention to guarantee a minimum repertoire for all learners. The contrast between these formal courses and those of informal nature is that while the latter may provide more information for some part of the audience due to life experience and background knowledge, the former attempts to ensure that every learner receives a minimum knowledge deemed necessary for future life.

In other words, the creation of this basic body of knowledge generates a common vehicle through which educated learners can communicate and understand the world and society to which they belong. This minimum set of symbols create a common means through which peers can discuss and create new knowledge, solutions and definitions on top of which, in turn, other solutions and definitions can be based, thus creating a cycle.

It is considered that every step of education leads to the acquisition or is derived from attitudes, and thus many schools have in their mission to modify or to teach certain attitudes such as chivalry, ethics, study habits or, some even more specialized courses aim to teach salesmanship, negotiation, technical skills of many sorts or even oratory skills — each with its corresponding attitudes deemed correct.

It is important to notice that Gagné does make the distinction from the attitudes that are learned through education form the ones needed to get an education in the first place — such as study habits and how to approach problems — and the ones gained after a period of formal education — civility, oratory, negotiation, technical skills. However,

TABLE 1 – Events of instruction and how they relate to the learning process, reproduced from (GAGNÉ; BRIGGS et al., 1992, p. 190)

Instructional Event	Relation to Learning Process
1 Gaining attention	Reception of patterns of neural impulses
2 Informing learner of the objective	Activating process of executive control
3 Stimulating recall of prerequisite learning	Retrieval of prior learning to working memory
4 Presenting the stimulus material	Emphasizing features for selective perception
5 Providing learning guidance	Semantic encoding; cues for retrieval
6 Eliciting the performance	Activating response organization
7 Providing feedback about performance correctness	Estabilishing reinforcement
8 Assessing the performance	Activating retrieval; making reinforcement possible
9 Enhancing retention and transfer	Providing cues and strategies for retrieval

it is noted that every attitude must resemble each other in their formal properties.

Finally, motor skills are activities which involve muscle movement, brain activities and the senses in order to create an interconnected and continual collection of atomic movements — the part skills — that are organized in such a manner as to create a complete activity, such as swimming, cooking, playing or writing. The skill must for each part be learned individually and posteriorly integrated in a complete motor skill. This is how to consider the learning process a success.

These general classes, despite being useful for categorizing the learning, give little insight about the learning process per se. For that matter, Gagné described how to organize the event of instruction in the table reproduced in 1.

These events are divided in three groups: The preparation, composed of events 1, 2 and 3; the Instruction and Practice, composed of events 4, 5, 6 and 7; and, finally, the Assessment and Transfer, composed by the events 8 and 9.

The events presented in table 1 are the steps described by Gagné for an effective learning process. The nine steps are created and performed in succession in order to optimize the retention of the subject to be learned. The learner must be guided through all these steps by the instructor and each of them has the purpose of activating some specific cognitive process.

Initially, the teacher tries to gain the student's attention, either by appealing to the learner's interests, with some evocative mental imagery or with some intriguing question.

It is necessary to notice that eventually it is not enough to use verbal communication to gain attention. An interesting phenomenon might do just as fine, specially in the disciplines of chemistry or physics — color changing liquids or fast moving objects get the attention of learners splendidly.

Having the attention of the pupils, the teacher may then inform about the learning objective. This step, although trivial, is of vital importance, as pupils will use this information for posteriorly perform the assessment of what they have learned and will — quite rightly — feel frustrated and feels "off track". This communication must take into account the cognitive capabilities of the pupils, as in some cases the students will not have enough linguistic repertoire to understand what is being asked of them.

Afterwards, the teacher may evoke previously learned concepts to create new knowledge. Gagné states that new ideas are mostly combination of previously learned ideas and concepts, hence the importance of building over previous concepts.

At this point the students are ready to be presented to the stimulus material through which the learning will occur. The wrong stimulus will naturally result in the wrong skill being learned — if pupils must learn how to program computers and they have no access to computers, they will learn only how to write programs on paper, for instance. The stimuli being presented must emphasize the features that determine selective perception, the keywords or key concepts that the pupils should pay attention to.

The examples used as stimuli must allow for the creation of the core concept as well as possible, for learning colors it is important to present the learner to several objects of the same color; for learning quantities, multiple objects in the same quantities; for learning adjectives, several nouns with the same quality, etc. The concept must be kept as general as possible while being kept as pure as possible.

With the concept understood, the learner is ready to receive some learning guidance. In this step, the teacher encourages the student to combine the subordinate concepts in order to create a line of thought to create the rule to be learned. This is a student-driven process in which the didactic material and teacher have limited part in, depending on the content to be learned — to tell the pupil the name of any given anatomical feature is far more effective than trying to make it be "discovered". Mathematical rules that are "created" by the student are naturally internalized.

Then, a demonstration is in order. Asking the learners to show what they have learned is the purpose of eliciting the performance. This may be done through a series of exercises, questions or any kind of demonstration in which the pupils must convince themselves that they have actually learned the concept.

At this time, the instructor may deliver some feedback to the student. This step must convey how correct the learner's performance was, how the learning may be perfected, and how much room for improvement there is. This communication may be formal or informal, oral or non-oral, as it just needs to communicate clearly the correctness of the pupil's performance.

Afterwards, the pupils must have the performance assessed, they must prove to the tutor that the desired learning has taken place. This assessment must be done in a manner both reliable and valid. There must be a check on how the pupil applies the (supposedly) learned rule through a series of examples that extrapolate the basic levels of understanding; it must both create an environment in which the skill is displayed beyond doubt and that reinforces that the desired learning has, in fact, taken place — does the learner know the difference between electric current and electric voltage? Does the learner know how to draw the human figure? Does the learner know the correct grammar?

Finally, as previously stated, new concepts are built on top of older ones, hence, the necessity of recalling learned concepts and exercising them regularly. Knowledge transfer must be emphasized as well, as the ability to apply the same concept in different situations may be used to expand the limits of the student's knowledge and enable them to learn other concepts, with a higher degree of complexity.

2.3 CONTENT ANALYSIS

To allow for the assessment of the player experience during gameplay, there was the need to employ a technique that allowed for the evidencing of personal experiences. The main challenge with this data collection is that the data is subjective, and cannot be measured with traditional techniques.

So as to create the necessary conditions to interpret subjective data, a proper theory must be utilized to allow for the classification of excerpts and to create a relationship between them. One of the means through which this is possible is by the application of Content Analysis (LEUNG; CHUNG, 2019). This process allows for a researcher to interpret the meaning of subjective data, codified in written or visual form (SANDELOWSKI, 2010).

This kind of analysis uses a set of analytical steps, aiming to define the element under analysis and other characteristics regarding the meaning of such phenomenon to answer questions regarding what is it about, how the phenomenon can happen or even which its consequences could be. To be possible to acquire such answers, this analysis must be based mostly in qualitative techniques. Or, as explained by (LEUNG; CHUNG, 2019):

> [...] researchers use CA [Content Analysis] to achieve two main purposes:

> (a) to uncover how a phenomenon is socially arranged and how it implicitly or explicitly works or (b) to describe how participants explain their behavior, to generate a cumulative understanding of the phenomenon. (LEUNG; CHUNG, 2019, p. 829)

The Content Analysis theory admits the existence of three classes for this technique, the summative content analysis, the directed content analysis and the conventional content analysis. Each with its own characteristics and applications, ranging from the most naive but well structured to the most interpretative but flexible.

The summative content analysis is an application of a technique used to explore the contextual meaning of words in a text (HSIEH; SHANNON, 2005). By focusing on the most superficial and the apparent meaning of words or even phrases, this application of the technique is often reduced to merely counting words or phrases and verifying the meaning in which they are employed.

The directed content analysis approach is also called conceptual analysis and is used to provide credibility to a theoretical framework or theory or even to extend it. In this process, initial codes or categories are created from the existing literature and if other codes are found within the data, the analyst must create a new category and expand the theory.

Finally, the conventional content analysis is the most subjective form in which this theory is applied. In this case, the reference regarding a subject is so limited it is not possible to create themes beforehand and this task must be performed while interpreting the data. In this case, researchers must assign codes to the parts of data that they feel are relevant and interpret them as they feel it is appropriate.

The main feature of this technique is that it assumes that in both natural and social worlds, there are unobservable entities that have the ability to cause observable events (BHASKAR, 1998). In other words, this theory admits that some phenomena can cause observable effects, even if they are happening within an agent, such as sensations, feelings and experiences. (SANDELOWSKI, 2000) describes this concept in the following excerpt:

> In conclusion, the qualitative descriptive study is the method of choice when straight descriptions of phenomena are desired. Such study is especially useful for researchers wanting to know the who, what, and where of events. [...] If their studies were designed with overtones from other methods, they can describe what these overtones were, instead of inappropriately naming or implementing these other methods. (SANDELOWSKI, 2000, p. 339)

As such, the application of the technique can evidence the experiences of a subject relative to one specific phenomenon that may not be able to be explained through the material world. Such ethereal characteristic can complicate the analysis, as there is no direct manner through which to measure the events directly, thus the need to create a procedure capable of evidencing the most intangible aspects of phenomena from social or psychological natures, for example.

In this section, three techniques utilized in the application of content analysis are detailed, each with their characteristics and limitations. The methods are presented below in the form of elements used in the data gathering and interpretation process.

2.3.1 Thematic Analysis

Thematic Analysis is the technique used to determine themes and assign them to excerpts in the data body. In this case, the themes are defined as the reflection of the different meanings words or phrases have in the context of the body of data.

> Thematic analysis (TA) is often misconceptualized as a single qualitative analytic approach. It is better understood as an umbrella term, designating sometimes quite different approaches aimed at identifying patterns ("the- mes") across qualitative datasets. (BRAUN et al., 2019, p. 844)

In this case, the themes are defined as patterns of shared meaning. This allows for the definition of these elements to follow a pattern as well, in which ideas revolve around a central theme that should be defined either before or after the interview take place.

One of the main applications of this theory is to evidence themes for the proper analysis, based on the meaning of some data in a determined context. This analysis, hence, is performed in a shallow perspective, as the analyst must define the themes, and evaluate the composing elements in a predefined theme. The results, then, typically lack the deeper analysis of other techniques.

However, this procedure can be used to identify the themes of work for future preprocessing of the data. At a later time, these divisions will come into play and be utilized by other analysis procedure.

2.3.2 Narrative Analysis

In the next level of abstraction there is the narrative analysis, in which the analyst must review the data and expand the explored meaning towards a greater level of abstraction. In this case, physical world elements replaced by the themes cause or enable the comprehension.

In the context of narrative analysis, the researcher is only interested ib the personal experiences and subjective transformations for which the analyst can gather the information subject to the interviewee. It is important to verify that some themes were defined during the research preparation and others will arise from the analysis of the body of evidence of such experience.

2.3.3 Discourse Analysis

The final analysis, the one that provides the most freedom for the analysts, is the discourse analysis. In this theory, the analyst verifies which themes arise spontaneously from the data elements. Only during the analysis the themes will present themselves and be formatted in a manner that will be possible to account them or to verify their existence.

This theory is based in the understanding that language evidences beliefs and experiences. For this reason this analysis is used when there is the interest to gather information regarding the subjective experiences from the interviewees, materializing the ethereal through codings and themes and allowing for the observable effects from the unobservable causes to be studied.

It is interesting to notice how the themes reveal concepts that exist outside cultural interpretation. In other words, the themes are independent from culture and educational background, equalizing how ideas are conveyed and analyzed to aggregate to a theoretical framework, no matter how mature it is.

In this case, the application of such techniques allows for the verification of the experiences of a subject of interest within an area of analysis, in a manner that is both independent from culture or educational level. In conclusion, these techniques can act as modulators for conveying experiences, that would typically be discarded as being too subjective to take in consideration.

2.4 CHAPTER CONCLUSION

Hence, by investigating the virtual environment in the light of the game development theories, it is possible to consider how the trainees will approach the virtual environment and how they will feel encouraged to keep using it as they progress on the training activities. This will lay the basis for defining how to keep the trainees interested in the learning environment and allow for them to train continually and maintain their interest as during prolonged periods of time.

By taking into consideration the pedagogical theory described in the text, the trainees will be able to profit from the learned lessons that can be translated into the real world and for real applications. In this manner, the outcome for the trainees will be maximized and the objectives for the learning activities will be reached as early as possible.

It is interesting to notice how the educational and the game design contents are complementary to each other, in the manner that the educational theory requires the trainees to engage in lessons with ever increasing difficulties and to repeat the training with maximized attention to the process.

However, the challenge to verify if the trainee has felt like the developed system could be used repeatedly needed to be answered still. To satisfy this need, the discourse analysis theory could be used in order to analyze if the trainees felt that they would get back to the system recurrently.

By coordinating these three theoretical basis, it is possible, then, to provide tools to both design a virtual learning environment and verify if the built artefact is perceived as useful in the training process by the trainees and instructors.

3 BIBLIOGRAPHIC REVIEW

The main objective of this chapter is to present the papers relating the theories used in the development of this research. These papers are related to the research questions, presented on section 1.3, and the research was made in order to define how the themes were approached by the scientific community and to, finally, create a research opportunity in which a relevant contribution could be performed.

3.1 MDA FRAMEWORK AND GAGNÉ'S PEDAGOGICAL THEORY

To create the correspondence between the MDA model and Gagné's theory, a bibliographic research was conducted in order to evaluate the available literature on this subject, an initial search was conducted and the results were then refined to include only the texts of interest. The results then provided a body of texts aligned with the research needs for this work. Table 2 details the keywords and the results returned by CAPES' online repository.

The focus of the current bibliographic review was to determine if there is a defined theoretical basis regarding the connection of Gagné's instructional theory and the game design MDA framework that should provide a manner through which it is possible to develop a virtual training system in a consistent manner. This bibliography review connects to Research Questions RQ01 and RQ02.

TABLE 2 – Research criteria for games and instructional design literature. Source: ellaborated by the author.

Keywords used in search	**Results Found**
"Qualitative research"AND "user experience"AND "thematic analysis"	1211 results
"Qualitative research"AND "user experience"AND "thematic analysis"AND "instructional design"	9 results + 4 results that was discarded for being older than 5 years

In (RAVYSE et al., 2016), the authors made a systematic review of 72 articles, in which the MDA framework is not considered to the analysis, and even though a section is dedicated to getting feedback from the learners, the techniques described are based on indirect observation, not taking in consideration the direct feedback from the players, as proposed in the current research. This technique is only explored as a means without acknowledging the player as a source in insight in the game design process, or, more specifically, not seeing the game through the players' lens.

The remaining potential bibliography does not correlate the MDA framework neither with Gagné's model, or any other pedagogical method, even though many initiatives regarding the use of game-based learning are frequently found in the literature. In (EL MAWAS et al., 2020), the authors detail the creation of a solar system game-based learning environment for desktop computers. During the experiment, the researcher divided the class in two groups, one of which took regular classes and one that was exposed to the game-based classes. Afterwards, both groups took the same test and the group which took the game-based classes fared better than the other. The authors do not detail the use of any pedagogical technique or game design technique to support the development of the learning environment.

In (NOKKAEW et al., 2020) the research conducted was based on developing a learning system that mapped how the learner created the knowledge model of a task learned through game-based learning. This verification occurred by harvesting in-game data through the use of automated mechanisms and verify the learning, not only by its outcome, but by the process as a whole.

The creation of a digital game artifact is described in (MONIAGA et al., 2017). The authors, however, detailed only a waterfall-based software development methodology used during the development of their game-based learning system as well as the instructional design used for the development. In this research, however, no feedback from the players was taken or there were any plans to do so.

In some cases, the researchers did a meta-analysis over game-based learning environments, such as in (TAYLOR et al., 2017), in which the authors use statistic's game theory to try and foresee which paths the players will take in a game-based environment and try to determine a priori the player's actions during an instructional event.

Other authors mentioned in their research both MDA and instructional design events without relating them, such as in (TORRES-TOUKOUMIDIS; RAMIREZ-MONTOYA; ROMERO-RODRIGUEZ, 2019), in which the authors enunciated a method for verifying the effectiveness of an already implemented game-based learning system. The authors detail how a game-based learning system could be seen by analyzing them through the MDA framework and, independently, through their instructional design, but not correlating both theories.

In his paper, (CHASANIDOU, 2018) discusses the design for motivation theme and how to get feedback on the user to develop motivation-based experiences, or to stimulate learners to recurrently interact with the created artifacts. In the described method, the authors used semi-structured interviews and theme division, in order to interpret the transcriptions and gather the necessary user feedback. However, this work has failed to acknowledge thematic analysis as the link between MDA and the instructional design stage.

This kind of analysis is not limited to digital games, as shown in (MAZA, 2018), which explores how analogical games can be used in game-based learning activities compared to digital games. In this paper, despite the author citing the MDA and how the instructional design phase should be conducted, it still makes no correlation between them.

In his article, citeHsieh2020 depicts the creation of another analogical game for learning. The aim is to create a game for teaching sustainable development to students taking a "Game Design Theory and Practice"class. For mapping the player's feelings, this research uses a Likert-Scale questionnaire to evaluate user experience and gather data from the players.

In (CZAUDERNA; GUARDIOLA, 2019), it is possible to find a summary of the general tone from the other papers. The authors propose a technique for creating only the instructional design without the game design or verifying the learner's output. The author states finding many difficulties in designing a serious game, as it is different from an entertainment game. The serious game must have an additional design step – the instructional design – which is responsible to pack the knowledge that the instructor is trying to convey to the learners into the gameplay mechanics and contents. The authors emphasize that there is no typical approach to design such artifacts and the theory does not emphasize the learning process itself.

Another conclusion that can be drawn from the selected papers is that the game-based learning experiences are not frequently designed by game designers, but by other professionals who feel the need to convey a learning experience differently, or to deliver a traditional message in an innovative manner. As there is no further theoretical Game Design foundation, this results in designers that do not see the player as part of the process, as the player input is not always taken into consideration.

The application of a Game Design methodology such as the MDA framework, for example, could strengthen the theoretical basis of such works. By dividing a game in the Mechanical, the Dynamic and the Aesthetics layers, a designer would already be taking in consideration, respectively, the rules of the game, the interaction among the rules and the feeling they evoke on the player.

In the cases in which the player's opinion is gathered, the design professionals resort to techniques such as including in-game mechanics that try and assert the players opinion and performance, measuring the artifact on the Dynamic layer, leaving outside the Mechanics and Aesthetics layer of the MDA model. In some of these studied cases, the player's opinion is taken using their experience, which corresponds to the Aesthetics layer. However, for the designer did not take into consideration organic themes that the players could bring up in a semi-structured interview by applying a Likert-Scale questionnaire or, in the case of (CHASANIDOU, 2018), the themes were not correlated to an established game design framework, such as the MDA model.

Hence, in the matter of the current discussion regarding player feedback and the MDA model, this research will explore:

- How to gather direct and detailed feedback from learners;
- Provide a tool for aligning the tutor's expectations and learner's perception.

3.2 INSTRUCTIONAL DESIGN QUALITY AND EFFECTIVENESS

In this case, there was not the possibility to refine the search without compromising the quality of the bibliographic search. Table 3 details the keywords and the results returned by CAPES' online repository.

The purpose of this bibliographical analysis is to assert if there is a defined theoretical basis related to research questions RQ03 and RQ04 detailed in secion 1.3. In this case, the bibliography was assessed to verify how the theoretical basis of instructional design related to the process effectiveness, as well as what to try and define whether there is a widely adopted concept of what is the definition of effectiveness in the instructional context.

TABLE 3 – Research criteria for instructional design quality and effectivenesss. Source: ellaborated by the author.

Keywords used in search	**Results Found**
"instructional design"AND effectiveness AND "virtual environment"AND motivation	638 results

Due to the quantity of results, only the 30 most relevant results were chosen to be analysed. The most cited papers were considered to be the most relevant, hence, the 30 most cited papers were considered to be the most relevant.

The instructional design for effectiveness and trainee motivation in the virtual environment is currently a new and mutable subject. A literature review was done in the Scopus database by (BODILY; LEARY; WEST, 2018) that analyzed the trend of research topics on instructional design techniques. The authors, then, conclude that the diversity of the subject is as widespread as the international community around it.

Moreover, in (WATT; SMITH, 2021), the authors conducted a literature review regarding serious games designed for learning and elaborated guidelines to aid the process of game-based learning in Serious Games. The authors base their analysis in the Social Learning factor and the motivation factor, which improve the learning outcome.

The authors of (LURIA; SHALOM; LEVY, 2021) revisit the self-determination theory of motivation, which states that learning succeeds when brought about by autonomous rather than controlled motivation, or, when the learners' motivation is intrinsic, rather than extrinsic. In this case, the authors analyzed how students get motivated in a gamified environment, which would enhance the intrinsic motivation.

Furthermore, the authors propose to categorize a learning task by their objectives, defining the interrogative and the imperative goals, or, goals that the learner wants to achieve versus goals the learner is told to achieve. Another key topic in the article is regarding the rewards and punishments by associating the interrogative goals, that yield deep rewards without the fear of punishment, in contrast with the imperative goals, where the primary motivation is to avoid punishment. Even on interrogative goals, the reward should not be too big, as it may have a derelict effect by freezing the learners by the fear of not getting the reward, which itself might be seen as punishment.

However, as concluded by (OLMEDO-TORRE; MARTINEZ; PEÑA, 2020) in the instructional design for these learning environments, active methodologies should be preferred, as it creates a learning environment that appeals to the pupils autonomy and can act as an equalizer of gender, economic differences and visual environment perception facility. By creating an active and motivation based learning environment, the pupils can reach their full capabilities.

Furthermore, as described by (BACK et al., 2020), the technologies employed are positively correlated to the student's engagement and motivation of learning complex subjects in the most effective manner possible. In this study, the authors created a CAVE environment to teach neuroanatomy and to implement a collective learning environment, focused on rich spatial information and embodied interaction in a gamified learning environment.

In the developed environment, the pupils could manipulate or dissect brain sections as desired. The authors, then, concluded that this training method was more effective than textbook study and the group that most benefited from the virtual learning environment was the one with the lowest spacial ability, who has the most difficulty in making mental spacial representations from textbook diagrams and images.

Finally, the authors of the study conclude that the CAVE environment acts like a modulating technique to the specific needs from different pupils. This technique, then, would allow for better communication between peers and an improved learning experience for the learners with the most difficulty.

The authors of (YOUSEF, 2021) narrate the creation of an AR learning environment in which primary grade students would be presented to puzzles that could modify geometrical shapes to solve them. To verify the effectiveness of the learning environment, the authors then presented to the learners the same problem in the physical format, in which the problem solving rate was lower, as the authors stated that "Pupils adopted an optimal mindset for learning while utilizing the AR application."

To develop the AR application, the authors used the multimedia learning theory, in which the pupils have the opportunity to act with creative freedom and get practical experience in exploring solutions. Finally, the paper concludes that the creation of an AR application did enhance learning motivation and quality.

Other researches, such as (OBERDÖRFER; LATOSCHIK, 2019) used game-based learning as a means of providing a more concrete application to abstract concepts, such as the teaching Affine Transformations. This mathematical and theoretical concept is, according to the authors, a challenge to teach due to its abstract characteristics. The authors, then, proceeded to create affordances through which the learners could maximize their learning outcomes and classifying the knowledge in two great areas, the procedural knowledge (the tacit knowledge) and the declarative knowledge (the explicit knowledge).

In this research, the authors created two learning environments, a VR-based one and a destop 3D based environment. Both of them allowed for the pupils to experiment with spacial transformations and improve the learning process. As a final conclusion, the authors point out that although the VR environment improved the learning quality, they detected usability issues that they believe prevented the learning outcome to improve further.

Another research that aimed to create a more concrete environment for a theoretical subject was shown in (SAFADEL; WHITE, 2020). The authors created a VR-based learning environment to test students on the spacial structure of DNA, which allowed for the manipulation and experimentation with the DNA in order to enhance learning through the visual representation. Furthermore, to improve the learning aspect of the environment, the authors have create multiple visualizations to improve learning.

To verify the learning improvement between the traditional and new environments, the authors divided the pupils in two groups: one group that consisted of 29 participants visualized the structures using a 3D viewing mode and another group, composed of 33 participants visualized the same structures in the form of a VR environment. In both cases the groups could rotate and analyze the molecules as necessary to better understand the elements and, by the end of the process, the pupils took the same test and the students exposed to the VR environment achieved higher grades in the final test in general. As a final conclusion, the authors point out that the largest score improvement happened at the lower end of the learners abilities, increasing more drastically in the student group that showed the greater difficulty in spatial orientation.

Hence, the virtual reality environment acted, in this research, as an equalizer between students with higher and lower spatial abilities, even though both groups could visualize data in 3D and interact with the models as they pleased. In other words, the VR-based learning system achieved the greatest effect on the students that would, otherwise, have the most difficulty.

(PLUMMER et al., 2021) described a case study that took place during the 2020 pandemic, in which the authors detailed how they kept coaching psycho motor skills during the pandemic in a learner-centric manner that allowed for pupils to carry out training programs in a remote environment. The learners were encouraged to share their works between each others and to encompass communication skills focusing on feedback most specifically.

The authors, thus, finalized the research by pondering that the students were overemphasizing the academic skills, including the knowledge acquisition aspects over interpersonal communication and the ability to motor skill coaches to actively provide feedback to practitioners.

One other aspect of student-centered learning is that due to the greatest autonomy the students have, they created learning networks, as reported by (ARDITO; CZERKAWSKI, 2021). In this study, the authors mapped the learning networks students create while in a virtual study environment. The author mapped how the subjects interacted in the virtual environment and compared between tutor-centered and student-centered learning environments. In this context, the learning networks presented by the latter are wider and more decentralized than the former.

VR is a teaching resource which can be used to create learning environments that encourage students to explore and practise freely. In (KIM et al., 2020), the authors create a VR environment in which the learners can train design-based gardening and bouquet design allowing for the trainees to train freely and exercise their creativity.

However, the researchers encouraged the pupils to use the VR environment along with paper design. Hence, the trainees could design the floral arrangements and execute them in the VR environment. The authors conclude that this learning pipeline is optimized for learning, and finish by concluding that the traditional instructional means is not to be replaced by Virtual Reality, but to complement each other.

In (CHANG et al., 2019), the authors detail the development of an interior design learning environment using Augmented Reality that allowed for the pupils to manipulate physical elements corresponding to the interior design components and to test different configurations. As for the methodology, the authors used Keller’s Attention, Relevance, Confidence and Satisfaction learning motivation model to verify the learning outcome in terms of students' motivation and learning quality. Finally, the authors conclude that pupils that use AR technology show heightened learning quality and motivation.

(CHANG, 2021) further detailed the application of Keller's Attention, Relevance, Confidence and Satisfaction learning motivation model as a means to enhance learning interest and motivation, concluding that Augmented Reality does improve learner motivation and learning quality, as that technology improves students' concentration on the tasks.

Regarding professional development, still, (AVCI; O'DWYER; LAWSON, 2019) propose a professional development method called flipped professional development. In this case, the professional trainer is acknowledged as the key component, that needs to be constantly engaged in professional and personal development and learning as a means to provide better formative contents to the learners. To allow for this to happen, the trainer should be seen as more of a mediator rather then a centralizing figure, allowing the necessary available time for their own formative process.

Regarding multiple instructional media materials, (VOGT et al., 2021) theorized that the presentation of pictorial materials along with auditory description of a learning material could improve learning and retention. The authors created a VR environment in which an animation was displayed to the learners and a textual resource in the form of a recorded voice over. Then, the authors divided the learners in two groups, one that was exposed first to the VR animation and one that was exposed first to the text recording. For more advanced concepts, the optimal approach was to present the recorded text and then present the animation. In this case, the recording can direct the learner's attention to specific points of interest, which the learner can visualize in the animation.

In (HWANG; SHIN, 2018), the authors demonstrated that the cognitive load on the learners could be reduced by elaborating cues that showed to the students information regarding virtual elements and how to interact with them. The main conclusion, though, was that cueing did not help reduce the cognitive load on new users. In this audience, this technique did not produce any difference in the outcome. However, on returning users, the cognitive load was reduced, as the cues elicited the learner's memory and the learned lessons.

To further explore the theme, the authors created a 3D animation and added cues as well. In this case, however, the authors observed an increase in cognitive load and facilitated recall tasks. The authors conclude, then, that cues work differently from media type to media type and that there is not always a negative relation between cognitive load and recall tasks.

(OU; CHU; TARNG, 2021) narrate the development of a virtual wetland that allowed for pupils to explore the environment in virtual reality with the help of a teacher.

The researchers divided the students in two groups, one that used the virtual reality environment and one that did not. The group that undertook the virtual reality classes reported higher satisfaction with the learning experience and it was also more effective than in the group that had classes using traditional learning materials.

As a means to study how the learning activities should be designed, (GARCIA-CABRERO et al., 2018) used the Collin's cognitive apprenticeship model to design online activities that would meet the students' requirements for learning and for professional development. The authors concluded that, when the right conditions are met, online learning can be used to motivate higher-level critical thinking on the learners.

(MUBAYRIK, 2020) creates a manner to which they could evaluate the expectations of adult healthcare learners regarding distance learning. To assess the learner's perception, the authors presented the audience with a structured questionnaire, for which the researchers found that 67.9% of the learners had previous experience with distance learning courses and felt that these kind of courses were advantageous, as they could be taken remotely and easy to access.

As a conclusion, the authors stated that the pupils demonstrated a positive attitude towards distance learning that could be used to maximize the learning outcome when an institution thinks about implementing distance learning systems. In other words, field professionals were proven to be motivated to take distance virtual learning experiences as part of their daily routine and do engage voluntarily with learning environments.

(ZWART et al., 2020) details a similar experience for a mathematics course aimed at nursing students. During the digital course experience, the authors noticed that the pupils became less confident on their own abilities when presented only to the digital learning materials. To counter these effects, the authors determined that three conditions should be met: 1. the teacher should provide pointers from which the learners will be able to self-evaluate; 2. the task conditions should be discussed previously and 3. the teacher and students should discuss rules for online interaction during which the teacher should support the sense of efficacy in the pupils.

In (COOK et al., 2018), the authors defined three instructional scenarios for training endoscopy and divided the students in two groups. In the first group, the pupils had a predefined sequence of tasks and in the second group, the students were free to decide in which sequence the task should be executed. The groups were, then, further divided in a time-constrained activity and in a quality constrained activity. The authors conclude that the group that had a sequential framework got better results than the other group. However, the group that got the time constrained activity presented better learning outcome and the group that was assigned the quality constrained activity, also denominated the success oriented group by the authors, presented higher task finalization rate.

Finally, other researchers focused on gathering data from the pupils training in virtual environments, such as (LÓPEZ-GARCIA; MIRALLES-MARTINEZ; MAQUILÓN, 2019), that describes the gathering of the pupils' perception regarding how useful AR is in the school learning environment. To assert such a measurement, the authors utilized the Pressage-Process-Product learning model, in which the instructional design is divided in three stages:

- Pressage, in which the teaching context and the student characteristics are taken into consideration;
- Process, in which the learning process itself takes place, complete with the strategies to capture the learners' attention;
- Product, in which the learning outcome is assessed and compared to the instructors' expectations.

After taking into consideration the pupils' results, the authors concluded that AR heightened the students' attention and motivation, promoting collaboration and enhanced both the learning and studying qualities. Finally, the authors made a special note regarding the increase in motivation and attention during the instructional event.

To further explore the motivation among learners, (PARK; MIN; KIM, 2021) conjectured how the different players' profiles reacted to a gamified learning environment. The authors divided students from 91 different universities according to Bartle's Taxonomy of Player Types (achievers, explorers, socializers and killers) and subjected the players to a learning environment designed to teach the concept of supply and demand. Contrary to the expectation of the researchers, the player type on the Taxonomy did not influence the specific motivation. Moreover, the overall motivation was reportedly high regardless of the player profile in the Taxonomy.

From the presented bibliography, it is possible to verify that it is widely accepted that the use of virtual and augmented reality in education and professional training act as motivating factors, which, in turn, enhance the learning quality and voluntary student participation on the process. However, using the technology itself is not a guarantee that the instructional process will be successful, as there are other elements that are intrinsic to the humane nature of learning.

One of these conditions is that the trainees should be encouraged to take a more active role in their own learning process, while being presented to a learning framework to guide their studies, otherwise, the process may undermine the pupils' confidence in their own abilities. Regarding motivation, it is possible to notice a positive relation between the application of rewards and the learning outcome, unless the reward becomes too valuable, in which case it might have a detrimental effect.

3.3 UX AND LEARNER FEEDBACK

To evaluate the available literature on this subject, an initial search was conducted and the results were then refined to include only the texts of interest. The results then provided a body of texts aligned with the research needs for this work. Table 4 details the keywords and the results returned by CAPES' online repository.

The current bibliographic research relates to research questions RQ03 and RQ04, as there is a need to assert if there is in the bibliography any generally accepted manner of collecting feedback and applying UX for virtual learning environments. This relationship is relevant as the UX theory states that systems that the user feels that are most effective to accomplish their tasks. In this matter, the data gathering process is a vital process as it allows for the specific definition regarding what is considered affective or not.

TABLE 4 – Research criteria for user experience evaluation and learner feedback. Source: ellaborated by the author.

Keywords used in search	**Results Found**
"Qualitative research"AND "user experience"AND "thematic analysis"	1211 results
"Qualitative research"AND "user experience"AND "thematic analysis"AND "instructional design"	9 results + 4 results that was discarded for being older than 5 years

In (YEE et al., 2020), the authors detail the creation of a SMS-based system for educating women with gestational diabetes mellitus in their daily self-care routine. To assess how the participants felt about the tutoring process, the researchers used semistructured interviews to gather qualitative data and analysed the interview transcripts through thematic analysis. This enterprise, though, was a single time effort, and the researchers did not detail how, or if, the feedback would be used in future iterations of the same system.

In the same subject, (ZHU; BASDOGAN; BONK, 2020) discusses the necessity of medical students to be able to properly develop an instructional design for educating the public regarding health issues and how this fact is often overlooked by various medical degrees. During the course of the research, the authors asked medical students to design a training system for the general public and then answer questions base on the design process. To analyze the data from the interviews, the authors used thematic analysis to define what was the rationality used during the activity design.

In (ALYAMI et al., 2019) the authors narrate the creation of a 3D serious game for training medical history taking and divided the students in two groups, one that undertook lessons with the serious game and another that was presented to the traditional training materials in PDF text files. The authors, then, collected student feedback on the system using thematic analysis to interpret the qualitative data from the interviews. However, the authors did not disclosure if or how the data would be used to guide further system development.

In (DOUMAS et al., 2021), the authors designed and implemented a system address bullying prevention and handling in low-income rural schools. In this research, thematic analysis was used as a means of evaluating user experience, without making any connections with the instructional design and not integrating this process as part of the app development life cycle.

In (SHIH; VELAN; SHULRUF, 2017), the authors described how they studied the learner response to virtual e-learning technologies and collected data regarding the students' favourite points in a virtual environment. To analyze the data, the researchers used thematic analysis, which allowed them to verify that the main points were time availability and community interaction. It is necessary to observe that in this research no learning system was developed,

This technique was also used in (OLIVEIRA et al., 2021), where the authors conducted an exploratory research regarding the use of emergency computer aided learning systems during the initial steps of the COVID-19 pandemic. To assess how the students feel about the used techniques, the researchers interviewed students regarding classes conduction and teacher to student interaction. In order to analyze the data, the authors used thematic analysis to evaluate the students' feelings and experiences.

Another example of such application of this technique is reported in (ANDERSON; NORTHCOTE, 2018), where the researchers conducted an interview in order to assess the viability of virtual music training and rehearsal. To make such verification, the authors reviewed studies about the subject and analyzed the data through thematic analysis.

In (CASANOVA; ALSOP; HUET, 2021), the authors detail how thematic analysis was used as part of the development process to increase learner's agency when giving feedback on the courses taken. The authors used thematic analysis to analyse how the feedback was conducted, and not as part of system development.

Finally, (TRACEY; HUTCHINSON, 2019) describe the use of empathic design as a means of analyzing and detailing the development of the Virtual Hospital serious game. In this study, the authors used thematic analysis to understand the learning environment designers main concerns and their thinking through the whole process.

To analyze learners' reaction, the authors used a Likert-scale questionnaire to rate how the objectives were met as well as the activity's effectiveness and quality. To gather further information, then, the authors applied an open-ended questionnaire to the trainees and used five descriptors to assess how the group worked during the experience.

The gathered papers showed that thematic analysis can be used as part of system development to gather information regarding the users' opinions. However, as far as the bibliographic review could show, the thematic analysis technique was not used to include the user feedback in the design and development of future iterations of systems nor as a part of the instructional design.

The bibliography shows a gap that refers specifically to the process of taking the feedback and using it as a means to improve the performance of a system in a way that retains value to the user. As the thematic analysis is more widely used in the Humane Sciences than in Computer Science, it is comprehensible that this connection was made only partially, without including the feedback data into the system development process.

3.4 CONCLUSION AND RESEARCH OPPORTUNITY

After extensive bibliographical research, it is possible to conclude that virtual and augmented reality technologies are in lieu to becoming the next key educational technologies, allowing teachers and trainers to complement classroom information by presenting the instructional content in new manners, as they can solidify abstract concepts, create representations of physical objects or even transport pupils to other places.

These technologies, however, do not present the intrinsic capability of improving learning conditions, as other factors must be taken into consideration before the technologies fulfill their complete potential. Without taking into consideration the human factors, it is possible that the learning experience, as a whole, fail.

Hence, the learning effectiveness is subject to circumstances others than the technological development per se, such as learner motivation and the instructional design elaborated for a given learning experience, and there should be a way of gathering such data and analyzing the instructional context of these elements. In a traditional teacher-pupil relationship, this information can be exchanged freely during daily interaction, which may not be possible during the development of a learning system.

As seen in the literature, learning systems benefit from active learning teaching techniques, in which the student is the primary actor in the learning process. In order for the virtual learning system to be effective, then, it should appeal to the trainees by satisfying their expectations and motivating the continued learning habit.

However, it was also possible to notice from the gathered literature that the developed games are seen as a one-time enterprise, that does not justifies creating the instructional design and in incorporating the learners' opinions in the system design process. This can result in the failure to meet expectations, both from the tutors and from the pupils.

As seen in the bibliographic review, it is not usual to utilize a framework that could be used as a guideline to the development of virtual learning systems aligned to the game design frameworks and educational theories. This gap shows a deficiency in the theoretical background. As the instructional designers do not have theoretical background to support their design decisions, they must turn either to motivation theory, instructional theory or user experience theory to create their virtual learning systems.

In order to fill this gap, this work advocates that there should be a technique that tie together the instructional design and the game design theory with a method to assert the students' satisfaction and motivation to engage in learning activities. Hence, the main focus of this research is to create a framework in which the instructional designer of the virtual learning system can assert the trainees' motivation and align the instructional methods with the expectations of learners.

4 TECHNOLOGICAL BACKGROUND

In this chapter, some of the virtual reality equipment will be explored. This is done not only as a means of presenting the makers and models of the said hardware — as the technology is fleeting and the current development pace is expedited — but as a means of presenting interface paradigms and interaction concepts.

This methodology was selected in order to enable a better understanding of virtual reality concepts and interaction possibilities through concrete examples, in a new area at time of writing of this document.

4.1 PERVASIVE INTERFACES

The design of virtual reality environments currently presents a change in the way the presence of the user is perceived. As gameplay from Playstation VR games or computer virtual reality games show, the environment is not designed around the presence of the user anymore. Instead, a world is idealized in which the user will have the possibility to enter, a world which will consume the user, a world in which the player can be immersed in order to get the most out of the experience. In a way, the player has become irrelevant in the process as there only exists an avatar while the player is immersed. Both entities, player and character, overlap in a gateway between the real and the virtual worlds, enabling new experiences for the player, and, as previously stated in chapter 2, a game is simply a means through which an experience is transmitted.

4.2 MOTION CAPTURE HARDWARE

The interaction with the virtual world must be performed by movement, be it either hand presence, full body motion capture or through simple head movements. For the input of those streams of data, specialized hardware must be used to convert the physical stimuli into electrical impulses, capable of being processed by software.

4.2.1 Google

Google started in the virtual reality area through ingenious crafted cell phone holders modeled after virtual reality goggles. The cardboard was the first attempt to create a virtual reality experience based on the cell phone.

The cardboard HMD concept was developed by Google to provide cheap virtual reality headsets and appeal to a wider audience. The whole concept gravitates around using a simple and inexpensive case to hold a smart phone in a HMD-like manner in front of the user, which will be the real active element of the system.

FIGURE 3 – The Google Cardboard concept. Source: (GOOGLE, 2017a)

This concept is to be used as a mean of popularizing virtual reality for a wider audience. Despite the fact that there are companies selling manufactured versions of the Google Cardboard (GOOGLE, 2017a), the do-it-yourself version of the equipment is still available. The on-line instructions for creating a case using cardboard, a pair of lenses, some Velcro, a rubber band and magnets may be used as a starting point for virtual reality.

This headset relies completely on the smart phone within the case to acquire information from the world around it — such as the way the user is facing, geographic location, sound output, sound input and any other relevant data — which makes this equipment directly dependent on the quality of the hardware embedded in the smart phone. This also means that there is no expansion possibility; if other measurement is needed, the smart phone must be replaced.

As smart phones are usually equipped with cameras, this solution has been idealized to be used for augmented reality projects. The main issue is that the camera embedded in the smart phones is usually displaced from the center of the device, creating the illusion that obstacles are in different places of the environment. This means that objects and obstacles appear as being in different places than the real ones, making it difficult for the user to avoid them, risking injuries for the user.

The input of this HMD is done by the means of the magnets discriminated on the materials list — as the host smart phone has the ability to detect magnetic fields. Otherwise, it is captured only by electronic compass and GPS data. In this configuration, the device must allow user interaction only by the head movement and geographical location.

Google Daydream is an attempt to implement a more complex interaction philosophy to virtual reality environments.

The Daydream was developed in order to enhance the available input options to the Cardboard HMD. The daydream concept is to use a joystick-like input device, shown in figure 4 to enable hand presence in the virtual environment created in the Cardboard headset.

FIGURE 4 – The Google Daydream concept; the cardboard-like case and the input device (GOOGLE, 2017b).

The Daydream controller sends to the cell phone inside the cardboard the position on the X, Y and Z axis in order to create hand movement inside the virtual world. The buttons on the controller can be used for further interaction.

However, small movements are still a challenge to process using only the host cell phone GPS. In order to create a more reliable hardware, Project Tango was developed.

Project Tango is the manner in which Google is trying to improve the sensoring hardware quality in order to provide a better experience to users of the Cardboard equipment. To accomplish such task, the raw data from the hardware is complemented by computer vision data. The objective is to mimic human vision using the computational resources available in portable devices. (GOOGLE, 2017b).

Three are the concepts that enable such advances: 1. Motion Tracking; 2. Area Learning; 3. Depth Perception. (GOOGLE, 2017b)

Motion tracking is the ability for the device to track its own position on the three dimensional space. The device must be able to analyze its position and return data not only about the device position, but also the direction which it is facing, rotation, tilting and world movement.

Area learning is the ability of the device to recognize and remember environmental features — such as doors, stairs, floor, ceiling, etc. It is merely the ability to recognize visual patterns within an environment using image processing algorithms. This ability is used as a software aid for the localization hardware embedded in the device. Additionally, the device can remember areas in which it has previously been.

The depth perception feature allows the device to be aware of the distance of objects in the real world. For project Tango devices, infrared light measurement technologies have been chosen (GOOGLE, 2017b). This technology acts to complement the data from other sensors so that the device can localize itself in the space as precisely as possible, as it recognizes room features and is able to acknowledge how far it is from them.

This last feature can be used as a way of scanning three dimensional objects in the form of a point cloud. This can be used to recognize the volumes and shapes seen by the camera.

4.2.2 Oculus

Oculus is a company founded in 2012 by Palmer Luckey aiming to develop Oculus Rift as a commercially viable HMD. It started a crowdfunding campaign to get resources for the manufacturing of a pioneer HMD. (LAVALLE et al., 2014)

4.2.2.1 Oculus Rift

The Oculus Rift — shown in figure 5 is a HMD designed and manufactured by Oculus. It provides immersion and head tracking to the user, enhancing the user sensation of immersion.

The device must be physically connected to the video output of a host computer through a cord that divides itself in two connectors, a HDMI connector and a connector. The device cord is kept on the back of the head, in order to minimize movement interference, as shown in figure 6.

FIGURE 5 – The Oculus Rift hardware solution with joystick. (OCULUS, 2017)

FIGURE 6 – Detail of the use of the Oculus Rift equipment, with the video cord on the left. (OCULUS, 2017)

It is necessary to keep in mind that however minimal, the movement interference must be considered. A person standing is likely to get entangled and fall over, should no treatment be given to the loose cables. This is not an issue in the Cardboard solution, as it has no need of wires.

The position tracking is handled by an infrared camera, the leftmost item shown in figure 5. This device is responsible to capture the image formed by micro infrared LED which is placed in the external part of the headpiece. This data is then processed by computer vision algorithms that determine the location of the HMD — in which location the wearer of the device is expected to be. (LAVALLE et al., 2014)

To determine the yaw, pitch and roll of the head, an array of sensors is used to determine the movement and rotation of the head.

4.2.2.2 Oculus Touch

The Oculus Touch input device, shown in figure 7 was created to complement the Rift, as it provides hand — or tomato (LABS, 2016) — presence. It is a device that groups both the functionalities of joysticks and fingers sensoring, as shown in figure 7c. The hardware captures the position of the fingers as well as the yaw, pitch and roll of the hands, in order to provide the desired immersion.

(a) Oculus Touch front view.

(b) Oculus Touch rear view.

(c) Oculus Touch utilization.

FIGURE 7 – Oculus Touch views and utilization. (OCULUS, 2017)

The implemented software can capture the position of hands and fingers as a software input and act accordingly, either by grabbing virtual objects, navigating the virtual environment or by any other possible interaction.

The manner in which the Oculus Touch device communicates its position and rotation to the host computer is similar to the one used by the headset, as detailed in (LAVALLE et al., 2014).

4.2.2.3 Oculus Quest

Unlike the Oculus Rift, the Oculus Quest does not need a host computer — it is a standalone equipment that embeds the processing power necessary to create a virtual reality environment without the need of a host computer.

4.2.3 HTC

HTC is Taiwanese company founded in 1997 to produce smartphones. Over time, the company diversified the product portfolio and engaged in the production of other equipments, such as headphones, mobile chargers, smart watches, fitness products and the Vive — a VR headset. (HTC, 2017)

4.2.3.1 HTC VIVE

The HTC Vive was created as an alternative to the Oculus Rift. It is composed by the HMD, as shown in figure 8a and a set of two joysticks, as shown in figure 8b.

Unlike Oculus Touch, the Vive joysticks do not detect fingers position. The device however, utilizes less connection ports than the Oculus (HTC, 2014) — only one USB, against three USBs of the Oculus.

(a) HTC Vive HMD.

(b) HTC Vive joystick.(HTC, 2014)

FIGURE 8 – HTC Vive hardware ecosystem.

The Vive uses a different concept to solve the motion capture problem. Instead of a camera capturing the movement of the device, a play area must be defined by the mounting of the base stations on the walls or other kind of fixation device. The devices must be facing each other, such as shown in figure 9 and they can communicate among themselves either through radio or wired connection.

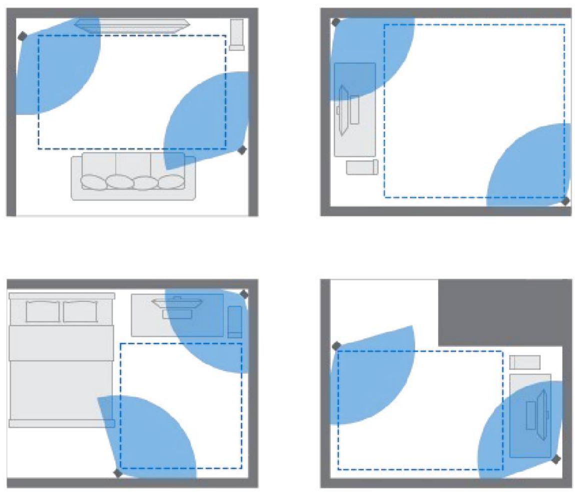

FIGURE 9 – Play area examples. (HTC, 2014)

The role of these sensors is to acquire infrared data from the headset and joysticks and to feed the host computer data about player‘s movement — just as the

Oculus Rift camera. This data is then used to compensate for hardware error and guarantee the accuracy of the movement acquisition data.

5 RESEARCH METHOD

This chapter details the process through which the research was developed and how the data from the various experiments were correlated among themselves. This analysis shows the purpose of the research and will allow future discussion of such subjects.

This chapter also shows how the three aforementioned stages were approached and how this work contributions were created and implemented.

Section 5.1 discusses the main concepts and premises that guided the development of the research work and the analysis of the data acquired from experimentation, used as a data analysis framework.

In section 5.2, it is explained how Knowledge Elicitation was used in order to detail the implementation of the system and the functionalities of the virtual elements which should be implemented.

Finally, section 5.3, demonstrates how the analysis of questions were performed in order to validate how the users interacted with the virtual environment.

5.1 PRELIMINARY DISPOSITIONS

This section states clear definitions and assumptions taken in consideration for the research in general and for this thesis in particular. The elements used in this work may have various definitions depending on the context in which they are considered. This section does not aim to impose any particular meaning for any of the terms cited along the text, but only to clarify to the reader how the elements were conceptualized during the development of the work at hand.

5.1.1 Project Scope

The virtual environment developed within the RV2 project comprises five different types of virtual experience, which presented progressive difficulty for the learner, described as follows:

1. Observation modality, in which the trainees can watch virtual electricians perform a preprogrammed activity;
2. Creation of scenarios, in which an instructor will create scenarios for the trainees to interact with. It is recommended that these scenarios represent real life situations, in which the instructor may explore problem based learning;

3. Instructional modality, in which the trainees will be immersed in the virtual environment and be presented with prompts regarding what they must do next;
4. Evaluation modality, in which the trainees will be presented with a scenario with which they have previously trained and will be evaluated in the activity;
5. Free interaction, in which the trainees may freely perform any activity in the virtual environment free of penalties.

These activities were modeled in order to provide the trainees with progressive challenges and keep them motivated to perform their activities. The creation of new scenarios provided both the trainee and the instructor with the possibility to create new forms of interaction and new maintenance situations in which the trainees could practice their skills.

Another requirement of the virtual environment is that it should motivate the trainee to interact with it in a frequent and spontaneous manner. To allow for such a usability feature, theories such as the PENS (Player Experience Needs Satisfaction) (SCOTT RIGBY, 2011), were used to provide the needed theoretical framework.

The PENS theory states (SCOTT RIGBY, 2011) that the players have three needs that need to be satisfied in order to keep them interested in the game: 1. The need for Competence; 2. The need for Socialization and 3. The need for Autonomy.

The creation of scenarios that the trainees can explore freely corresponds to the third need of the PENS model, the Need for Autonomy, in which the trainees are presented with a wide variety of choices and are able to choose from whichever they want. This need, however, implies that there is a range of choice, not that the trainees may choose anything they want. In other words, they may choose anything they want from a limited universe presented to them.

In a virtual environment, autonomy may be exercised freely according to the elements presented in the scenario. To allow for more interaction possibilities, the virtual environment must only present the trainees with more virtual elements.

It is interesting to notice that the trainees do not only exercise their autonomy in using the virtual elements, but on using the virtual elements in other manners, applying creativity to solve problems. To allow for this interaction, the instructor may create puzzles, in which the objects are utilized in an innovative manner, taking away scenario elements and allowing for different interactions.

This manner of inclusion of scenarios in the virtual environment shifts the focus in the learning context from the instructor, as the main character of the instructional event to the trainee, in consonance to the concept of active methodologies, focusing on the learning process of the pupil, and not the teaching process of the instructor. In such teaching methodologies, the instructor becomes more of a guide to the learning process rather than the main actor.

Even though the virtual environment implemented an active learning environment, the instructional process was based on the learning process described in (GAGNÉ, 1992). According to the author, the process begins with the instructional design, in which the teacher maps the learning event, all of its prerequisites and how the learning will take place to assure the success of the instructional event.

5.1.2 Effectiveness in the Context of the Live Line Training System

Effectiveness is one of the functional dimensions for the analysis and design of UX in applications. The definition provided by (ISO, 2018) is that efficiency is the "accuracy and completeness with which users achieve specified goals".

This definition packs in itself a complexity that must be understood before finally defining the term as used in this research: as stated in subsection 5.1.1 the research project documentation considered two types of users: the learners and the instructors, each with their own set of requirements. Even though the instructor software module was not implemented in the present version of the virtual learning system, this type of user still had to take into consideration.

The main functionality of the system, or the Minimum Viable Product, was a use case in which the instructors fed one learning activity to a repository and allowed for the trainees to access the training scenario either as directed by the instructor, for a training exercise, or as desired by the trainees themselves for independent study. These functionalities were observed in the final version of the research project, albeit only one training scenario was developed due to the complexity of programming the activity steps. The use case diagram of the implemented system is shown in figure 10.

This does not mean that the system was not designed to satisfy the needs of the instructors, as the virtual environment must have their knowledge embedded in it, as well as their training necessities. To allow for the modelling of events, the instructional design phase was executed along with the game design step.

With this change, formally, the instructional designer had as much power in the development of the system as the software designer, but the fact remains that the instructor is an actor apart from the development team and should be treated as a user. Hence, the instructional design should be thought of as an activity apart from the system development.

The second kind of user to be taken into consideration are the learners, as they will be the ones to consult the learning activities repository for training scenarios, and they should do so voluntarily. Hence the need to certify that the learners perceive the

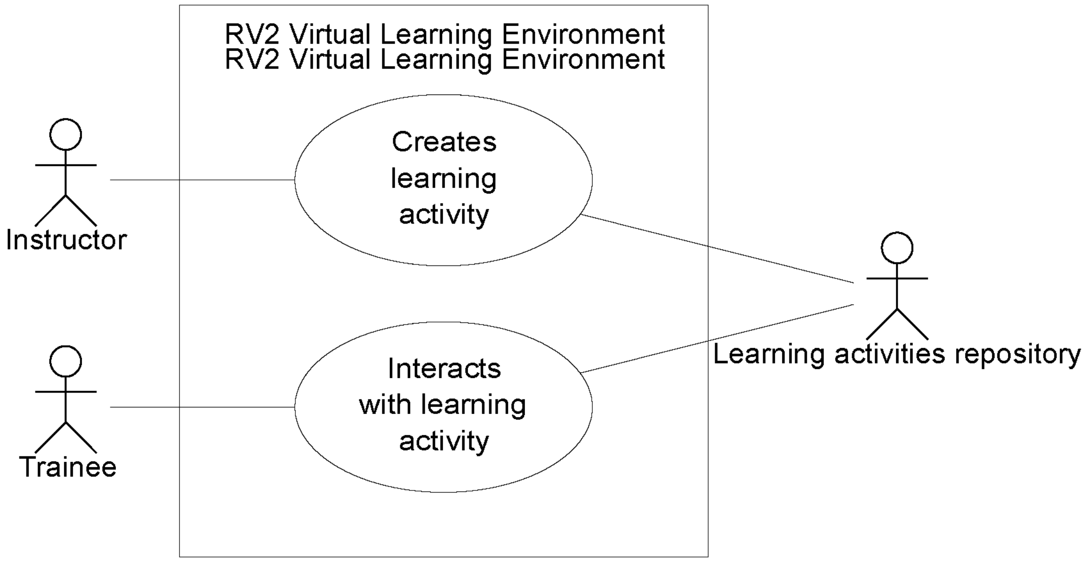

FIGURE 10 – Use case diagram for the main functionality of the RV2 Virtual Learning System.
Source: Elaborated by the author.

virtual learning environment as effective, to increase their probability of voluntarily using the training system recurrently.

To satisfy both user profiles of the virtual learning system, the effectiveness of the virtual learning environment was defined as how well the system would be able to deliver the experience intended by the instructor to the learner and could comply with the expectations that the learner has of the virtual learning system as well. This definition aims to take into consideration the professional maturity of both instructors and trainees, that have particular expectations regarding the use of the environment.

5.2 SYSTEM DEVELOPMENT

The development of the virtual system was divided in three stages: 1. the design stage; 2. the development stage and 3. the validation stage. This work is not intended to present the whole development process, as this research was developed in the context of the RV2 project, that counted with numerous professionals and research works. However, all of the stages had special needs that had to be taken into consideration in order to be completed and this work created the tools needed for the implementation. Figure 11 depicts the development process and the distribution of roles in the development of the project - in green, the parts developed by the author of this thesis; in blue, parts developed by the team or in the bibliography.

In the operational development, the project had three teams: 1. A development team for the frontend; 2. A development team for information modelling and; 3.A team of specialists to provide the necessary knowledge regarding the processes to be modelled. This division was created in order to allow for the development of a comprehensive environment, through which the appropriate technical expertise would be embedded in

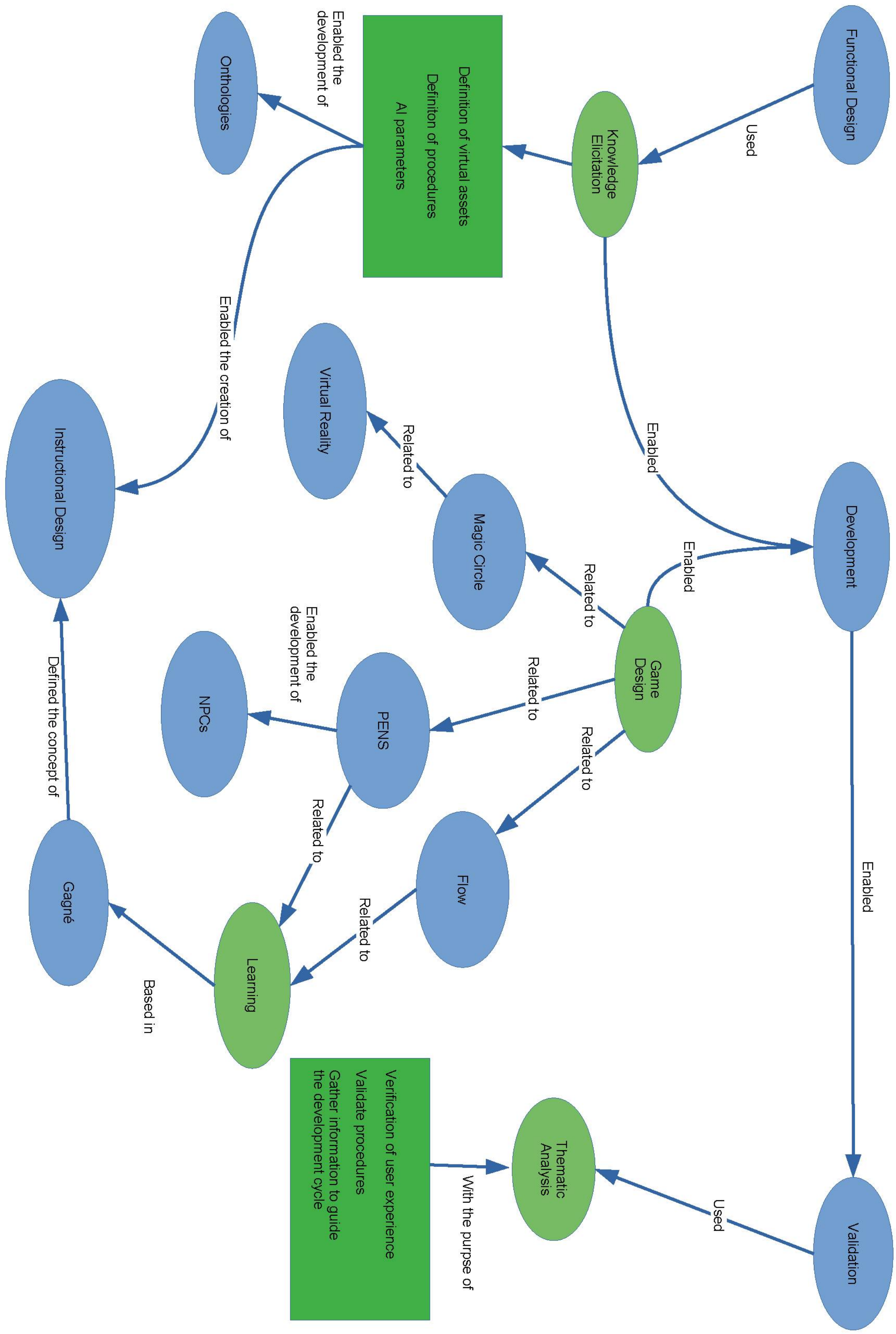

FIGURE 11 – Diagram of the project stages and the processes that were used in order to implement the virtual environment. The elements in green describe the elements the author created for the project. Source: Elaborated by the author.

the system as correctly as possible according to the technical and safety procedures to produce a training system as accurate as possible.

However, to enable the modelling of the virtual learning system, the process had to be reduced to its individual activities and their correct execution process. However, this proved to be a challenge, as the development team discovered that the process is fluid, even though the defined safety rules and technical procedures should be respected at all times.

This characteristic prevented the creation of a comprehensive and accurate instructional design, which corresponds to the activity described by (GAGNÉ, 1992) responsible for mapping the knowledge needed to successfully create a learning activity. Hence, in order to enable the creation of the instructional design for the selected activity, it was necessary to elicit the tacit knowledge the maintenance training specialists had.

In order to define these elements, a procedure for knowledge elicitation was developed as a means to define both the elements and stages necessary to complete the whole activity. The modelling should take into consideration how the elements were to interact among themselves in the virtual environment, which implies that not only their visual aspect should be defined, but their behavior as well.

As the intent of the virtual environment is to allow for the trainees to train unrestrictedly on their own free will and to become a meaningful experience to the learner in order to maximize the learning potential. These concepts take into consideration the psychological needs of the player/learner for creating an environment in which experimentation is encouraged.

Finally, in the validation stage, it was necessary to verify that the virtual environment did, fulfill its purpose and created value for the trainee. In this case, as the environment was developed with not only objective requirements, such as implementing tasks and creating virtual elements that behave like their real life counterparts, but also subjective ones, such as creating a feeling of immersion, enjoyment and safety for the trainee, another kind of analysis was devised.

In this case, the interest was not only in the system usability, but also on how the trainee perceived such interaction. This analysis was performed in order to assert how motivated the user was to keep interacting with the system and their motivation to use the virtual environment as a learning and testing tool.

In order for the system to present an efficient learning experience, it must be equipped with a database containing the learning requirements for any given maintenance activity. Hence, an instructor must feed them into the software system and save the learning activities in a repository for learners to use in a later time.

The RV2 project originally stated that there should be a software module to allow for the instructors to design learning activities and to monitor how the learners achieved the results in the virtual environment. Due to time constrains, this module was not implemented. In its place, the software implementation team programmed an activity in the instructional environment.

Due to further time constrains, the development team decided to implement only the replacement of the pedestal insulator activity. This activity was chosen by the instructors that work with the project team due to its complexity and rarity; this procedure is so rare that there are no records of being performed in the field and it has one of the highest steps count on the maintenance repertoire. Some activities are even subsets of the chosen maintenance procedure.

The development team initiated the process by studying both the training material for live line training and the documentation of the equipment used in the maintenance activities. After this literature review process, the questions were submitted to the specialists in live line maintenance, in order to define the final details.

However, this process proved itself ineffective, as the specialist did not know what the development team needed in order to advance the development and the development team did not grasp the maintenance concepts enough in order to formulate relevant questions. In this context, it was necessary to develop a method that enabled the development team to ask the proper questions to the specialists and to be able to create the description of the virtual environment from these answers.

The necessary knowledge had to be harvested from the training instructors, and, despite the existing documentation, the activity modelling showed itself to be a challenge, as the manner in which the trainees could execute these steps was open-ended. In a counterintuitive manner, despite the steps for high risk maintenance activities are well documented, maintenance professionals have complete freedom on how to execute them, depending on the concrete circumstances found in the field activity.

This autonomy reflects the level of specialization required from these maintenance professionals, who can determine the best course of action to address the problems found during work activities. Furthermore, it is routine for the maintenance professionals to develop new tools and techniques, which adds a layer of challenge to the activity modelling, as the virtual environment must be equally open-ended.

To document these requirements, the development team undertook a series of interview sessions with the activity instructors to assess the series of instructional steps to be taken and due to the malleable nature of the activity, the development team could not reach a consensus as to how to implement the training procedure. To solve this problem, an interview method was created to enable the mapping of such activities.

It became clear that a Knowledge Elicitation technique was needed in order to allow for the creation of the game asset's behaviours and to plan the internal workings of the system. These techniques were used to allow for the detection of patterns used for the execution of maintenance procedures.

To be able to elicit the necessary knowledge, a system was created to allow the simulation of the real-life field activity with the following requirements:

1. The activity had to be simulated without actually mobilizing the team to the field. The maintenance team is not always in the same city hence, so performing a simulation of the maintenance activity could imply costs and implicate a complex scheduling activity;
2. The focus should be kept at the maintenance process as much as possible. In this opportunity, the team should not consider what is possible and what is not possible within a virtual environment, just focus on how the activity is conducted;
3. There should not be worries about the technical implementation. Team members who do not posses implementation skills should not feel uncomfortable in discussing ideas and exchanging experiences;
4. The prototype should allow for rapid iteration. The prototype components should be easily manufactured and should be discarded and replaced as needed in order to allow for the modeling of the procedure to be better understood by all participants;
5. Should allow for the exchange of ideas of the participants and not hinder the discussion during the replacement of obsolete components.

For that matter, a low-fidelity prototype was developed to assist on the definition of the maintenance stages. In this technique, the development team is only interested with how the system should function. The mains goal is to abstract the game assets, as they are not relevant to the process at this time, to allow for the analysis on how the process is conducted - or, how the virtual environment should function, disregarding the implementation details.

5.3 LEARNER INTERVIEW AND USER EXPERIENCE

This section details the interview process created to assert how the trainees perceive the instructional platform, how useful they feel it is and which additional features should be included in the development process. This is not a trivial matter, as frequently the users are not aware of which features should take precedence in the system implementation or have unrealistic expectations regarding the features to be included in the system.

Eliciting requirements is the purpose of requirements engineering, as stated in (SOMMERVILLE, 2015):

> The requirements for a system are the descriptions of the services that a system should provide and the constraints on its operation. These requirements reflect the needs of customers for a system that serves a certain purpose such as controlling a device, placing an order, or finding information. The process of finding out, analyzing, documenting and checking these services and constraints is called requirements engineering (RE).
>
> The term requirement is not used consistently in the software industry. In some cases, a requirement is simply a high-level, abstract statement of a service that a system should provide or a constraint on a system. At the other extreme, it is a detailed, formal definition of a system function. (SOMMERVILLE, 2015, p. 102)

The elicitation process, however, is not always seen as a direct process (KASAULI et al., 2017; GROEN et al., 2017). Thus, this activity is often regarded as vital in which stakeholders should be involved, although frequently the user is not integrated in the process. In their work, (GROEN et al., 2017) detail the problem with this approach in RE:

> Traditional RE approaches usually involve a limited number of representatives in interviews or focus groups. Advanced RE approaches applied in market-driven RE enable companies to directly interact with key stakeholders using ad hoc feedback-gathering channels. However, these approaches miss the opportunity to continuously involve large, heterogeneous groups of users who express their feedback through a variety of media. This means developers can't consider the diverse backgrounds of user subgroups when they're developing a product's next version. So, valuable resources for RE remain unused, and software products might not meet users' needs. (GROEN et al., 2017)

As detailed in section 6.2 and 7.3, a system usability is directly connected to how the user experiences a given system, and how to motivate the user to interact with it. In the context of a learning system, the objective is to create an environment that motivates learners to interact with it repeatedly, increasing the learning performance.

However, for training systems, and for the RV2 project in particular, it is not possible to overlook the final user, as the performance of learning depends predominantly in the trainee's dedication to the process. In order to keep the trainee motivated to interact with the virtual training, it is necessary to make sure that the experience perceived by the trainee is positive.

Usually, to assess how the trainees perceive the usability of any given system, a standard Likert-scale questionnaire is used in order to verify how a user perceives the system itself. However, these questions only provide information to be used to calculate a usability score, but do not provide information regarding which elements of the system should be implemented or reinforced. In this context, the traditional UX questionnaire is used only to guide a product's iteration on new versions.

Typically, to define how a product should be further developed, the developers conduct A/B tests (GROEN et al., 2017) in order to determine the optimal alternative to continued development. However, this process is based on the developer offering to the user alternatives to the implementation of new features, not a user-guided process.

We advocate that the users should be listened in the development of a solution, as a virtual learning system should be interesting to the trainees in order to maximize the engagement of the trainees and allow for independent studies.

In order to create such an environment, the traditional Likert-scale user experience questionnaire should be applied with discretion, as it does not gather any new information from the trainees, it just verifies how the trainees feel in a predefined manner towards the training system. Using a broader interview method, such as a semi-structured interview, it is possible to gather information regarding the aspects of the virtual environment that should be improved.

To assert information regarding the user experience, a semi structured interview was applied to the trainees and sentences were tagged according to the user experience requisites. Afterwards, the interview transcription was analyzed qualitatively, based on both objective and subjective characteristics, in order to create a score compatible to the consolidated user experience analysis procedure. Finally, the transcript was re-tagged with tags that appeared spontaneously from the trainee, themes that the trainee himself brought up in order to acknowledge which next steps would be interesting to the trainees.

5.4 QUALITATIVE ANALYSIS OF THE INTERVIEW TRANSCRIPT

Initially, to analyze the interviews, it is necessary to categorize excerpts from the transcripts by defining themes and assigning codes for each one. In the present case, themes and codes both received the same designation, in order to avoid confusion during the analysis process and both were adopted as the scales of usability and user experience, constituted by 1 Valence dimension, 3 pragmatic attributes and 2 hedonic attributes. These scales were presented in section 6.2.

In order to interpret the data, the interview transcript was aligned with the

6 scales of UX User Experience evaluated in the User Experience Questionnaire (SCHREPP, 2019). The excerpts from the interview were categorized according to the criteria shown in table 5.

To aid in the creation of these codes and to map them to interview transcripts excerpts, the RQDA software was used in order to facilitate the identification of the occurrence of themes and to identify which parts of the transcript were associated with each of them. In posterior steps, themes were defined from the interview transcripts and the codes were added to the analysis.

The coding of the text is done by reading the document and determining to which theme each part of the text belongs, by interpreting which were the ideas the interviewee was trying to convey through a part of the text. It is important to note that it is not necessary to constrain one excerpt to one theme, as a single excerpt may fit in more than one theme simultaneously.

The analysis process was done in three stages:

1. Thematic Analysis: In this part, the themes were defined. This part of the analysis is the most superficial one, in which the themes from the interview are defined and a preliminary counting is done to determine the overall context of the transcript.

   This is a preliminary analysis, to determine the main themes of the interview and to explore the main topics the interviewees wished to address. In this step, the guidelines of the interview interpretation are laid out and the transcript excerpts are marked according to each theme. To determine UX-related metrics, the themes used were, initially, the 6 scales of user experience.

2. Narrative Analysis: In this part, the themes are aligned to form a narrative about the trainees experiences in order to explicit their objectives.

   This is a deeper interpretation of the interview in which the themes are organized in order to create a narrative which describe the interviewee's previous experiences and their future goals and purposes based on how the situation presents itself currently. In this matter, the interviewees express these subjects thorough a story that has a plot that retains the complexity of the situation under exploration as well as their emotions and motivations.

3. Discourse Analysis: This is the most meaningful step in the analysis of the interview analysis. The discourse analysis technique defines sets of statements that share a pattern of meaning. This means that the analyst must pay attention to the form of language used; the choice of words and how they evidence beliefs and experiences outside cultural interpretation.

In this step, the analysis is directed towards the meaning of the words and how the interviewees use them to convey their ideas. These ideas are centered around the themes, defined in the Thematic Analysis stage. However, on previous stages, despite creating themes and identifying what the interviewees tried to communicate, in this stage it is taken into consideration how the ideas are conveyed in the interview in order to create a reaction independent from cultural interpretation.

The purpose of analyzing the discourse outside cultural interpretation is to allow for the discourse to be understood as the experiences of the interviewee expressed through the words, not the words themselves. In this framework, the language used in the interview allows to ponder how the interviewee feels about the aspects of the game and opinion about certain topics.

Parts of the interview were marked as each of these themes, in order to analyze what the interviewee expressed in each excerpt of the interview. Each excerpt was coded according to the appropriate UX theme in a non exclusive manner; if an excerpt matched more than one theme, the appropriate parts would be accounted for both themes.

To illustrate such a situation, consider the corresponding excerpt:

> [...]As I said there are many tools... If someone says "take this tool", the guy is not used to the way to use the tool, the way to assemble it, the way the parts fit to each other, the way you handle it... In the simulator, you have it all at hand, easy to use, you don't need to bring the truck from far away Londrina to another town.
>
> Things like this, with a lot of material and also the environment. When you're at the substation, you depend on the climate, you depend on many factors. In the virtual environment, you're there, you respect the distance in a virtual environment, in a relaxed and easy way, you don't depend on the climate, you don't depend on logistics. [1]

This quote, taking into consideration only the themes from table 5 has elements from both the efficiency and the novelty themes. Even if this whole quote shows how the

[1] **Original:** [...] Como eu falei, são muitas ferramentas... Se falar, 'pega esta ferramenta' a pessoa não está habituada com como se usa a ferramenta, como que monta, como que encaixa, como que se manuseia... No simulador, teria ali disponível, fácil para as pessoas usarem, não precisaria carregar um caminhão lá de Londrina para outra cidade.
Coisas assim, com muito material e também com o ambiente. Quando você está em uma subestação, você depende do clima, depende de vários fatores. No ambiente virtual, você está ali, respeitando as distâncias ali num ambiente virtual de forma mais tranquila e facilitada, não depende do clima, não depende da logística.

TABLE 5 – UX scales as documented in (SCHREPP, 2019) and the criteria adopted to classify interview sentences. Source: Adapted from (SCHREPP, 2019)

UX Scale	Description	Criteria to Define a Sentence
Attractiveness	Pure valence dimension, that signifies if the user likes the virtual training system, showing the overall impression perceived by the user.	This category is used when the interviewees talk about their feelings towards the virtual training system.
Perspicuity	Pragmatic quality that represents the facility to get familiar with the virtual training system, and its usage.	Used every time the trainees explain temporary difficulties, problems that they had to overcome during the training session or any kind of misunderstanding of the training system's functions.
Efficiency	Pragmatic quality that shows if users can perform their tasks without unnecessary effort.	In this category goes every account of how the virtual environment makes the training task easier, either by inserting more functionalities to the process or by eliminating effort from the traditional training process.
Dependability	Pragmatic quality that evaluates if the users feel in control of the interaction.	Sentences that express mistakes made due to complexities with the controls of the virtual environment.
Stimulation	Hedonic quality that assess if the users feel motivated or excited while using the product.	Sentences that express how the trainees would use the virtual environment in their routine training exercises.
Novelty	Hedonic quality that verifies if the product catches the interest of the users and is considered innovative and creative.	Sentences that express how the virtual environment introduces new resources to the training activity.

virtual environment makes the training task easier by taking away complexity involved in the training activity, which guarantees that it should be categorized in the efficiency theme, the excerpt "[...] no simulador ali teria disponível, fácil para as pessoas usarem, não precisaria carregar um caminhão lá de Londrina para outra cidade", however, could be categorized in the Novelty theme.

This second classification is due to the fact that the excerpt shows that the virtual training system inserted a novelty on the training activity — the creation of virtual tools to be used in the VR environment. Hence, this particular excerpt of the interview contributes to two UX scales, enabling the UX analysis as originally intended.

5.4.1 Predetermined Themes

After the creation of the virtual environment, it was necessary to assert whether or not the trainees had the desired experience, asserting that the designed usability performance had been achieved. According to the ISO 9241-11:2018 standard, there are three usability factors: The effectiveness, which corresponds to how completely and accurately the results are; The efficiency, which corresponds to the resources invested in order to get the results and; The satisfaction, which corresponds to the lack of discomfort to get the desired results. The framework that shows how these concepts relate with each other are shown in figure 12.

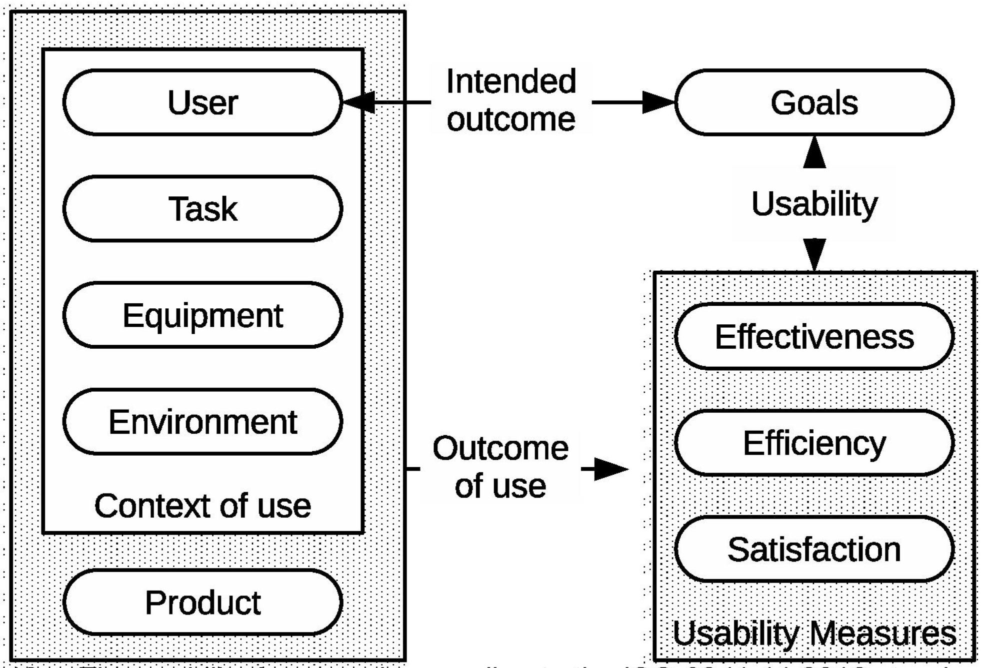

FIGURE 12 – The usability framework according to the ISO-9241:11 2018 standard. (ISO, 2018)

The ISO 9241:11-2018 standard considers not only the functional attributes of the system, but it encompasses how the user feels towards the system. These metrics are commonly referred to as the Hedonic Characteristics in User Experience

(RAUSCHENBERGER et al., 2013). In this new framework, how the user experiences the system is a relevant metric – as relevant as how efficient the system performs the desired operations.

The inclusion of such metrics creates a means to assess the extent of how a system motivates its user to keep interacting with it. This is accomplished by creating a pleasant experience in which the user gets involved in the process and uses it recurrently. (ISO, 2018)

For assessing usability metrics a questionnaire is usually used to assert how the user experienced the interaction. (SCHREPP, 2019) These questions are designed to evaluate key points of the interaction, namely:

- Attractiveness: If the users likes or dislikes the system;
- Efficiency: If the users must employ unnecessary effort to solve the tasks they want the system to aid them with;
- Perspicuity: If the users are able get familiar with the system easily;
- Dependability: If the users feels that they are in charge of the interaction;
- Stimulation: If the users feels motivated to use the system;
- Novelty: If the system is innovative and creative enough to capture the interest of the user.

These scales, pragmatic and hedonic along with atractiveness, follow a hierarchy and are composed of a series of dimensions. The Attractiveness scale, due to its wide interpretation is regarded as a higher level characteristic, with six dimensions; the other scales each have four dimensions. (SCHREPP, 2019; RAUSCHENBERGER et al., 2013) A schematic representation of these elements is shown in Figure 13.

The dimensions mapped to the usability scales are used to convey the meaning of the scales, and these dimensions are used in order to create the UEQ. Even though this document is used to verify how the user regards the interaction, this analysis is only relevant when the system functions, components and the desired values of each scales are defined a priori (ISO, 2018).

These elements are defined during the creation of the system and are derived from the description of the use objectives of the product, or which are the goals the users expects for the system to help them achieve. It is necessary to observe that the user's objectives may not be monolithic, it is possible that there is a hierarchy of primary and secondary objectives that the system meets or not, depending on its functionalities.

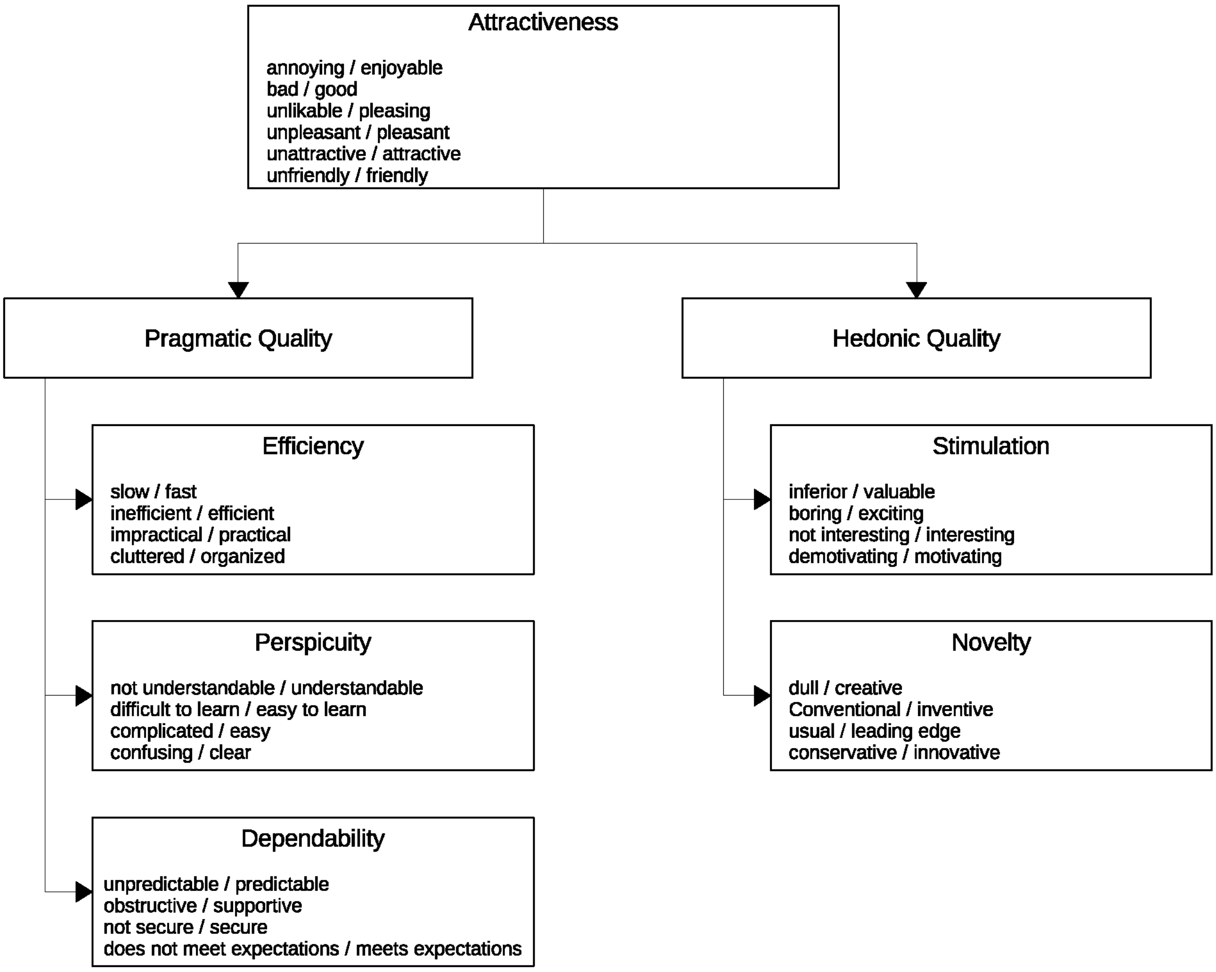

FIGURE 13 – Structure of UEQ . Reproduced from (SCHREPP, 2019)

As a manner of visualizing the interaction between the pragmatic and hedonic characteristics of a system, (HASSENZAHL, 2003) detailed the distinction between them and how the needs must be addressed by the developed system. According to (HASSENZAHL, 2003), the hedonic and the pragmatic usability characteristics of the system are independent and each one has a role in the perception about how the system satisfies the users' needs. The interaction between these two usability axes is shown in 14.

The (ISO, 2018) standard states that a system is developed to address a given problem users have, and this is the reason for undertaking the development effort it takes, so that, this mechanism discourages the developer to develop a useless system. This case corresponds to the lower left quadrant of figure 14, where both pragmatic and hedonic have a low significance, an unwanted usability characteristic.

A system, hence, may aid the users to accomplish tasks (the ACT quadrant in 14) and to express their personalities (the SELF quadrant in 14). These factors take into consideration not only if a product does what it was intended to do, but also if the users are willing to use the product repeatedly to accomplish certain goals. Therefore, acceptable systems are those that have a strong pragmatic characteristic and a weak hedonic characteristic, defined as a product that only serves a purpose, or a system that has a strong hedonic characteristic and a weak pragmatic characteristic, defined as a product that serves only as an extension of the users' personalities.

A system, however, that strongly presents both pragmatical and hedonic characteristics is deemed to be a system that will be useful to the users and that will be recurrently used to solve the problem it was designed to address. A system with these characteristics is the desired system, as shown in figure 14, as it serves for both the hedonic and pragmatic needs of the user.

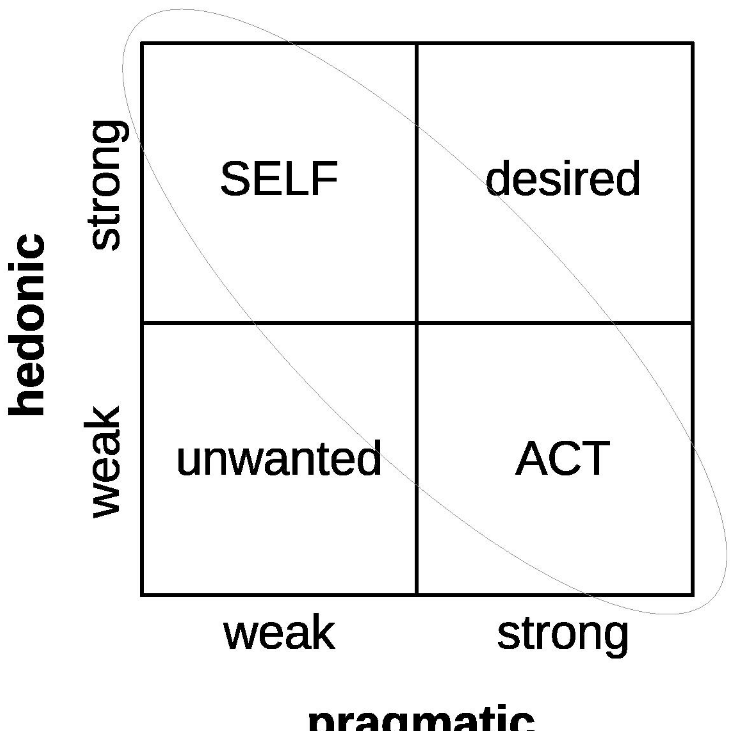

FIGURE 14 – How the pragmatic and hedonic usability features interact in usability. Reproduced from (HASSENZAHL, 2003)

The definitions of the system and its usability metrics were performed during the instructional design phases of the system design, in which the user's needs were asserted, as well as what the system objective would be. For educational systems, moreover, according to (ÁLVAREZ-XOCHIHUA et al., 2017), in educational computer games part of the motivation is how the user perceives the learning process - the more the users feels that they are learning, the more motivated they will feel.

Hence, (ÁLVAREZ-XOCHIHUA et al., 2017) expanded on the usability map illustrated designed by (HASSENZAHL, 2003) by adding a new axis, the learning motivation axis, distinct from both pragmatic and hedonic characteristics, as shown in figure 15. This new dimension is related to how and if the players feel that the game is effective in teaching the desired subject, either in a more pleasant or in a more efficient manner.

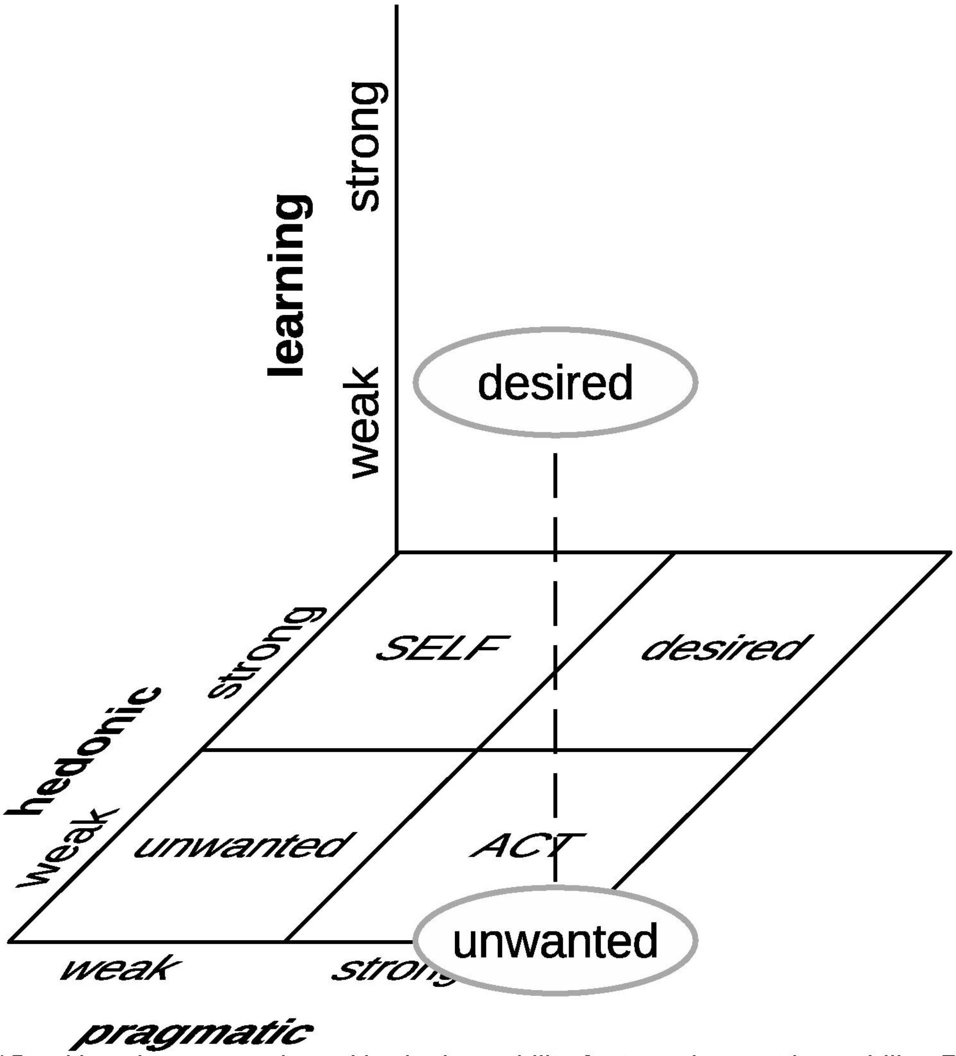

FIGURE 15 – How the pragmatic and hedonic usability features interact in usability. Reproduced from (ÁLVAREZ-XOCHIHUA et al., 2017)

However, the user experience is a subjective component inserted in this analysis, that is not related to any quantitative metric (HASSENZAHL, Marc, 2018). In this manner, a proper evaluation instrument is needed. Albeit a standard questionnaire was developed (SCHREPP, 2019), in order to evaluate how the users feel about the system using pre-defined verbs. In this questionnaire, the 26 scales shown in figure 13 are tested and both positive and negative meanings are evaluated.

However, to properly assess how the users feel, the qualitative characteristics must be taken into consideration along with the objective ones (BRAUN et al., 2019). In order to take into consideration such nuances, a semi-structured interview was conducted and the Thematic Analysis technique was used.

5.4.2 Organic Themes from the Interview

In a second analysis step, the interview was analyzed for themes that appeared spontaneously in the answers from the interviewees, henceforth called the organic themes. In this analysis, the mapping of themes is made without any previous assumptions, unlike in the first step, which the interview was analyzed in the light of the UX characteristics.

In this step, the interview was scanned for the themes that the interviewee talked about, in order to detect what the most important themes for the interviewee are. Assessing which themes are of importance to the trainees is an important part in determining the following stages of the development, as the importance of the system and its utility are a key factor of the system usability.

Differently from the previous step, the themes came from the excerpts from the interview in a coding process created from the interpretation of ideas in the domain of the interview. To perform this analysis, the interview was read and, when a theme was detected, the analyst marked how far the theme spanned and marked the corresponding excerpt.

These themes, reported by the interviewee, were the subject of the Narrative Analysis process. In this process, the motivation and objectives of the interviewee were noted and marked for every theme in the interview.

This process allowed for the determination of which were the objectives of the interviewee and how the system could meet them. Hence, the analysis could be used to determine the next development steps and provide a guide for the continued development of the virtual environment, preventing the investment of effort in resources that do not matter to the trainees.

This is important not only for indicating the subsequent development steps, but also how useful is a key factor to usability and the UX score of a product. So, this process must be used in order to create a road map to newer versions of the virtual environment.

5.4.3 Theme Identification Phase

This step was performed in two separate stages, one that tried to match excerpts from the interview to predefined themes and another that extracted themes from interview excerpts. This two step process was performed so as to allow for both exploration of expected patterns in the interview and new patterns to be perceived in order for new information to be acquired.

This process was designed to discover how the players feel regarding the virtual environment and what were their expectations when entering the virtual reality system. For the matching of interview excerpts with predefined UX themes, that would aid the assessment of usability factors, as well as the measuring the effectiveness of the developed system.

Hence, the themes detected and their motivations were as described in the following list:

1. Virtual environment simplification

   This theme aggregates the sentences in which the interviewee expressed that the reality in the virtual environment was simplified in comparison to the real world. This also encompasses every sentence used to express how a given task was simpler to accomplish in the virtual environment and the fact that it could be complex also in the real world environment.

2. Safety

   This theme aggregates all the sentences in which the trainee expressed concerns regarding the safety of the maintenance activity and of the learning environment, to which hazards the trainees get to exposed during the training procedure and how the trainees navigate these characteristics.

Afterwards, the items were analyzed in the view of the Discourse Analysis, which indicated how the interviewee felt towards the themes and how the proposed virtual environment helped in the training activity. This analysis was based not only on what the interviewee said, but also how the interviewee said it.

Finally, the safety theme when associated both with the real and the virtual environment, but with different approaches. This theme, when related to the virtual environment is approached in a positive way and when speaking about the real environment is regarded in a negative manner.

The next step of the virtual environment system was to test it with audience, test training activity and collect the opinion of the audience with the environment. There were two opportunities in which the system was made available to the public and in these two opportunities a questionnaire was applied to people who were subjected to the training exercise.

The system was initially made available at an internal event of the power company in which the public was heterogeneous and came from various sectors of the company, even from those that did not perform field work in live line maintenance. In the other opportunity, the public consisted of mainly live line workers, with various levels of experience and hierarchical roles.

The questionnaire was designed to provide insight about UX aspects and focused primarily in questions regarding the UX dimensions, both functional and hedonic. The questionnaire was subjective and recorded, hence, the interviewees could answer according to their experience and feelings and the answers were later transcribed from the recordings.

The interview transcripts were, then, subjected to the Thematic Analysis process, in which themes were mapped from the interviews collected from both opportunities. The theme identification process was performed in two distinct manners, on in which the interview was matched to the UX themes and one in which the themes were spontaneously identified from the interview transcription.

These themes were, then, accounted for and matched to the project's requirements where conclusions were taken from the body of data generated. This could show, then, the public's perception, were they the intended users of the system or not.

6 EXPERIMENTS

This chapter details how the experiments were conducted, the data was gathered and how the parameters defined in chapter 5 were used to produce results. This data will be discussed in chapter 7 to allow for the creation of a comprehensive framework to analyze the process of learner feedback and tutor knowledge harvesting.

By the end of the chapter, the experiments will form a complete framework, and we will present the process utilized to develop an instruction-centered virtual learning environment that brings the trainee into the design process and enables the active participation of both instructor and learner in the development of instructional systems.

6.1 SPECIALIST KNOWLEDGE GATHERING INTERVIEW

Initially, in order to create a virtual learning environment, the instructional data must be harvested, either from documentation or from the activity specialists. For the modelling of this process, the documentation did not offer much assistance, as the open-ended characteristics of the activity were too fluid and did not allow the necessary information gathering to take place and create a comprehensive learning environment.

To gather the necessary information, it was necessary to create an interview process that could harvest the desired knowledge from the specialists and to make it available to the system developers. Traditional questionnaires could not elicit the necessary experiences and proved themselves to be pointless after some frustrated attempts, suggesting that another kind of interview should be developed, as described in section 5.2.

To enable the interview process, a room was set with a play area for mounting a substation model with the aid of specially prepared playing cards. It counted with the presence of the lead developer, the lead designer, the research and development manager as well as the author's. The instructors were then asked to simulate the activity execution with the cards that contained the name of the components. Meanwhile, the lead developer could take notes and ask questions regarding the activity. Some cards used in this process are shown in figure 16 below.

The elements were organized in three groups: 1. tools; 2. structures and 3. others. An example of these elements is the insulator rod, categorized as "tool"; the pedestal in which the insulator is installed, categorized as "structure"and the rope, categorized as "others".

After defining which element would be in each category, a color code was

FIGURE 16 – Examples of cards prototypes. In orange, a cards representing a tool; In blue, a card representing an equipment and in red the objective card, which represents the part of equipment that must be replaced. Source: Elaborated by the author.

devised in order to create a visual identity to the card which corresponded to each type of element. Some of the cards that were created are shown in Figure 16.

The specialist working with the research team was invited to make the simulation along with two of his peers. Thus, this experiment was conducted with a joint group of three specialists in the area of live line maintenance.

This simulation focused on the maintenance activity to replace a burned pedestal insulator. This activity was chosen by the trainers themselves because it is an uncommon activity, so rare there is no record of it, as the last time it was performed predates the existence of the current recording system.

The mediator presented the cards to the specialists and familiarized them with how the process would be conducted. After the rules were presented, the simulation process was initiated by introducing the scenario and contextualizing the maintenance activity.

Initially, the cards showed the situation in which the defective pedestal insulator should be replaced and the surrounding equipment should be the same as the available in the field. The cards should be arranged in the same manner as the equipment in the same disposition would be arranged in the field.

After setting the experiment, the activity itself was initiated. The specialists were asked to separate which tools they would use in the field activity. This initial step was performed in order to simulate the beginning of the maintenance work – separating the tools and organizing them – and to verify that no item was missing. In this case, there were no missing components, but, if that was not the case, some spare materials were ready to be used to create more cards, as needed.

Subsequently, some roles were assigned. It was necessary to have a conductor for the process – the author of this document; the registry keeper – the head developer and the head artist of the team shared this role; and a mediator between technical and research teams – the research project manager. Each of these roles had specific attributions to perform:

- The conductor was in charge of keeping the specialists concentrated and discussing what they were doing on the task (thus, eliciting the desired knowledge) and to mediate any potential disagreement;
- The mediator was in charge of keeping the specialists team and the developers team communicating with each other as requested by the conductor. As he has both technical and academic backgrounds, he was able to provide insight both to the technical and the academic teams;
- The registry keepers were in charge of creating a list of the steps performed by the specialists during the activity and register this list in the form of simple instructions to be transformed in a knowledge database.

During the simulated activity, the specialists exchanged opinions about the maintenance procedure and spoke as if they were, in fact, in the field performing the maintenance activity. This feature did provide evidence that the specialists felt immersed in the maintenance activity and that the process aided with the process of remembering the activity process.

The tool selection continued during the whole process, as the specialist training instructors kept remembering items that they initially had forgotten. This action showed the main feature of a low-fidelity prototype, in which the materials are easily manufactured and disposed of and helped to put in evidence tacit knowledge that would not be easily visualized otherwise, without the aid of visual materials.

By having a physical representation of the maintenance materials, the instructors could focus on the activity and explain in a coherent manner the maintenance activity, beginning with the preparation phase and which materials should be ready for use. After the missing cards were added to the activity, the instructors were ready to begin simulating the replacement itself using the available material cards.

During the simulation of the maintenance activity to replace the pedestal insulator, while the instructors described the process with the aid of the cards, the system developers took notes and created a comprehensive list of the necessary activities. This served as the basis for the development of the virtual learning environment, as the activity would have to be hard-coded and there weren't any other activities in the instructional planning in this initial moment.

To indicate the necessary maintenance steps, the instructors moved the cards as they would in the real environment and assembled them in the manner that made most sense for them. As they used the cards representing the materials, the lead designer could ask questions regarding the equipment in order to model them as faithfully as possible.

The process also enabled the lead designer to create 3d models of the activity steps and to produce a visual guide to allow for the developers to use when designing the activity. One sample of such models is shown in figure 17.

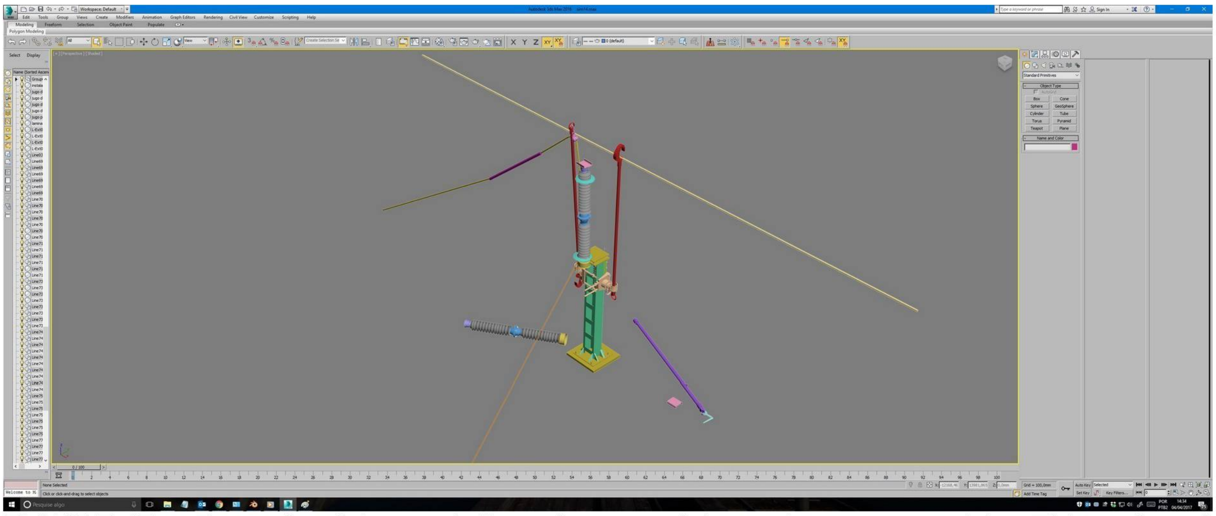

FIGURE 17 – Example of the modelling of a step of the maintenance activity. This series of modelled frames were used to help in the visualization of the maintenance steps during the development activity. Source: OneReal research group.

The creation of these frames allowed for a more comprehensive understanding to the process as a whole and permitted the creation of the activity task step by step, which allowed for the creation of the activity in the virtual environment. Before the application of such technique, the communication between the instructors and the development team could not happen in a satisfactory manner.

Even though this technique seems simple, it solved a complex problem; the developers could not understand which the requirements for the virtual learning system were and the instructors could not communicate how the activity should be executed.

This happened, as already stated, as a result of the activity itself being fluid and not having a well defined list of actions. By performing an activity in a simulated way, the instructors could convey the steps and demonstrate how the activity could be performed in a variety of manners, depending on the concrete situation present in the maintenance site.

By understanding this context, the developers could understand how a whole set of tools could be used to perform the same operation, and the fact that how the tools worked was not as relevant as what they actually do: it is not important how a hammer works, just that it is used to push something; it is not important to understand how a rope works, just that it is used to pull something.

Hence, it became clear that the modelling of the tools was not as important as the modelling of their effect in the activity. Or, for instance, a rope could be replaced by any other material that does not conduct electricity and pulls something, or a ladder could be replaced by anything that elevates the technician. In this sense, it is possible to say that the crucial element is to abstract the effect from the tool itself.

This allowed for a new understanding of the activity and the maintenance work as a whole, and allowed for the development team to implement the virtual learning environment. In other words, it allowed for the inclusion of the instructional design in the system development.

With the activities modelled, the developers could focus on creating the physical environment in which the maintenance activities occour. The finalized virtual environment can be seen in figure 18, figure 19 and figure 20.

In conclusion, this interview process aligned the system modelling activity and defined the rules through which the system should function and their algorithms and data structures, which corresponds to the Model layer of the MDA framework. This is also the function of the Instructional Design process described by Gagné and detailed as a preliminary step to his instructional events. In the case of a virtual training system, both the Instructional Design in the instructional methodology created by Gagné and the Model in the MDA model share the same function, and, so, can be fused in one single entity during the system planning and development.

6.2 TRAINEE INTERVIEWS

To allow for the trainees to provide the feedback for the training activities, the interviews were conducted in a semi structured manner, to allow for the open feedback from the users after a training session, illustrated in figures 21, 22 and 23. This feedback format was devised in order to maximize the amount of information possible to be extracted from the interviews, as it permitted the gathering of information besides that

FIGURE 18 – An aerial view of the virtual environment, with the substation equipments modelled and placed as in the real environment. Source: OneReal research group.

FIGURE 19 – A view of the equipments in the ground level. Source: OneReal research group.

which was explicitly asked.

In the context of a Likert-Scale questionnaire, the interviewee can only answer what was asked, without the possibility to deviate from the original question. This would not allow for the trainees to express their own ideas, just reinforce the ideas and concepts presented by the questionnaire designers themselves.

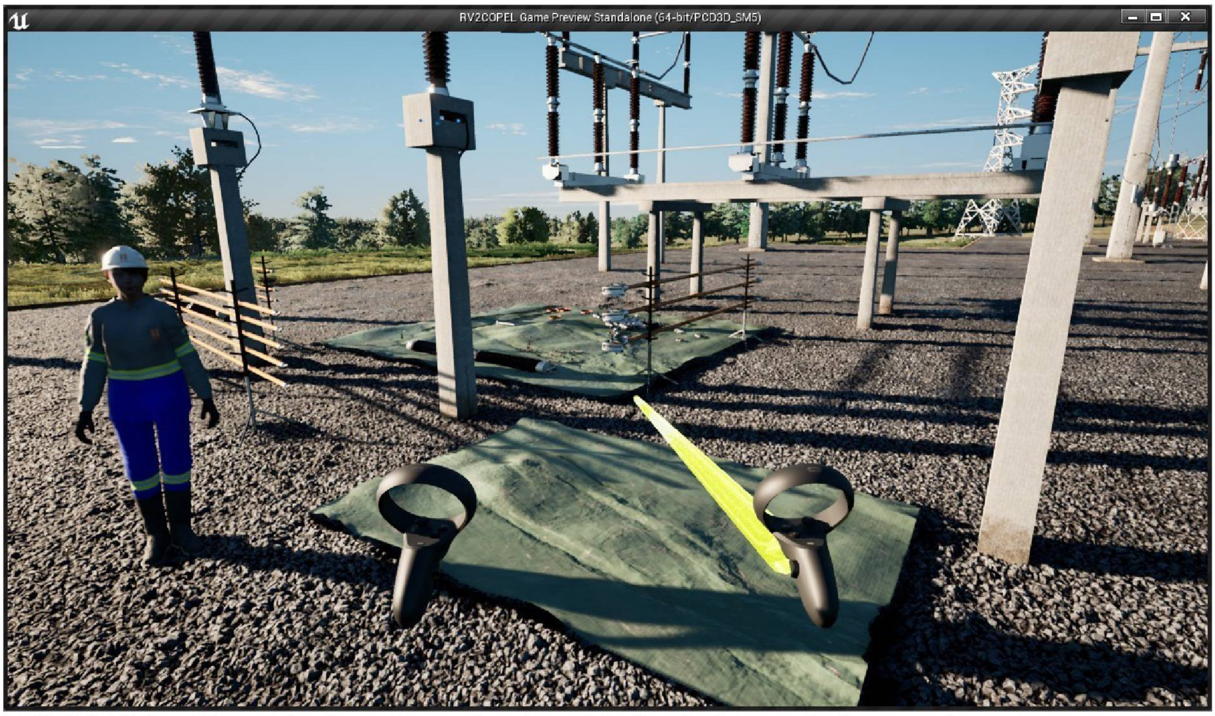

FIGURE 20 – The virtual equipments placed in the field, ready for maintenance procedures. This replicates the manner the equipments are placed in the field during maintenance activities. Source: OneReal research group.

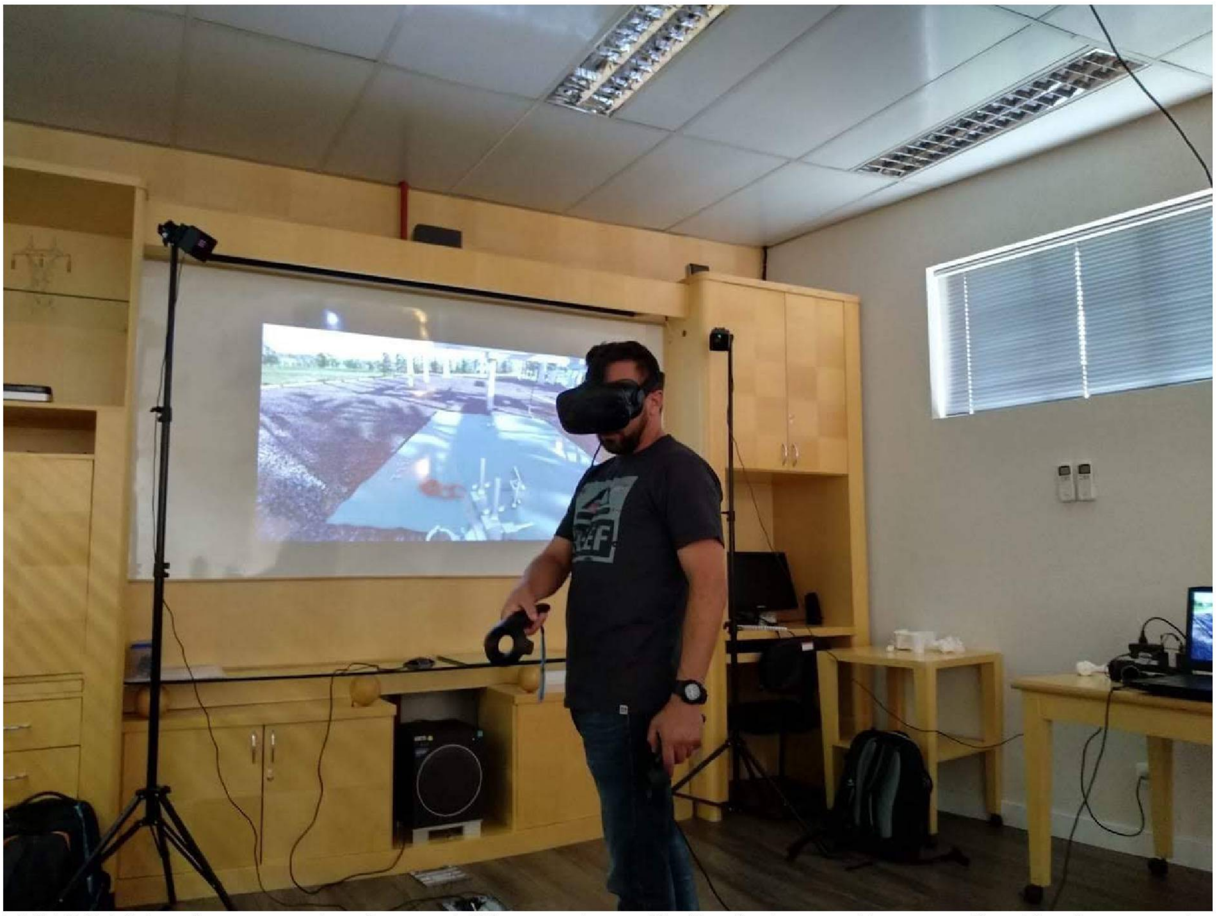

FIGURE 21 – An example of a usability session with the trainees. Source: OneReal research group.

FIGURE 22 – A trainee in a training session recalling the steps aquired in theoretical training.
Source: OneReal research group.

FIGURE 23 – A maintenance professional during a training exercise. Source: OneReal research group.

6.2.1 Participants

During the development of the RV2 virtual environment, feedback from many sources was taken, for the research, however, only the groups detailed in table 6 were taken into consideration, each gotten from in-person events prior to the 2020 COVID pandemic. The demographics taken into account for the research are shown in table 6.

It should be noted that both demographic groups work in the same electrical company, hence, are familiar with the corporate environment. However, only one of the groups has real life experience with the modeled activities, the other group has professional experiences in other areas of the company, albeit not too far away from the live line maintenance context, as they work in areas such as control rooms or engineering projects.

The system evaluation was performed in two stages, with predefined themes and with spontaneous occurring themes. The initial step focused on finding in the interviews evidence of themes related to the UX dimensions, as it could lead to the identification of how the users feel in a more comprehensive manner than with a Likert-scale questionnaire. After that process, the questionnaire analysis focused on identifying themes from the interviews to get a deeper understanding of the experience the users

TABLE 6 – Demographics of professionals that participated in the interviews. Source: Elaborated by the author.

Event	Demographics	Description
Live line workers that do not conduct maintenance.	5 interviews	This event was a corporate event in which the participants could interact with the virtual environment. The ones who had expertise in live line were asked to answer the questionnaire.
Live line workers that conduct maintenance.	8 interviews	This event was counted with corporate training sessions in which the workers took part and afterwards were asked to answer the questionnaire.

had in the virtual environment.

These themes were created by the selection of excerpts from the interviews and by the understanding of the reason why the interviewee used such sentence. By both trying to match the motivations to predefined themes a posteriori and by defining the themes, the interview process is expected to provide deeper understanding of the interaction between the virtual learning system and the user, as the themes can be used to determine what their experience during the training session was.

6.2.2 Predetermined Themes

To study the UX dimensions determined in the ISO standard, the interviews were scanned for the UX dimensions determined in it, and the interviews were scanned for the occurrence of such themes in the interviewees' answers. The criteria adopted to study and to map the themes was presented in table 5 and was adopted in both field and non-field professionals interview transcripts.

As it is necessary to determine which of the UX dimensions is more perceived than others by the interviewees, there was a need to account for the positive impressions of the themes as well as for the negative impressions and consider which theme had the most positive impressions compared to the negative ones. Each theme, then, is divided in two subthemes, one with a positive bias and one with a negative bias which will be deducted from the positive one.

For instance, sentences such as the ones below were accounted for the positive aspect of the Efficiency factor, as it indicated that the users felt that the system could help them achieve the desired learning outcome. Such examples are found in:

[...] you will be more than used to it from the start, even if it's a recycling course or a pre-training course. And from the beginning you'll feel more comfortable with the risks of the activity itself. [1]

The system is not at your disposal, you were at the disposal of the system. And there, it's different. It's the system that is at your disposal. There, you can do tests, you can experiment, you can stop and think with calm, much more than in the real work environment. [2]

Then, you have the opportunity to repeat the work you're doing in a better way. In real life, the risk itself prevents you from thinking sometimes.[3]

For sure! What I, to my mind, I have this idea, all that comes to add, not to lessen, then you came to add... As I said in the interview, when you follow the sequence step-by-step there, then you get to the environment and you have it all in your mind then as I do the step-by-step here, I will do the step-by-step there. [4]

Especially the newbie, I believe if this had been happening for longer already, I believe the routine with the real life would have advantages, so to say more flexibility. So to say, that when you're out and about, you already have this contact, this experience in the real world, you get this experience and you come to reality, so to speak, it will be much better.[5]

[...] but it's extremely important to review and recycle... To do the step by step of the task to be performed. Revise the procedures, the task, follow that step-by-step, because this is the case with the live line and with this virtual environment, to practice with safety, and you memorize that there is this logical sequence to be followed for the task. And this program of

[1] **Original:** [...] vai chegar mais habituado, nem que seja uma reciclagem e pré treinamento e já vai chegar mais habituados riscos da atividade em si.

[2] **Original:** O sistema não está a sua disposição, é você que está à disposição do sistema... E ali não, É o sistema que está a sua disposição. . .Que ali você pode fazer prova, você pode fazer experimento. . . Vale você pode parar pra pensar com muito mais tranquilidade que no serviço. . .

[3] **Original:** Então tem oportunidade você repetir melhor serviço que você está fazendo. O próprio risco é uma coisa que impede você de refletir bem. . .

[4] **Original:** Com certeza! O que eu, e o pensamento eu tenho esse pensamento, tudo que vem vem pra somar e não pra diminuir então você veio pra somar. . .Foi como eu falei na entrevista ele, quando você faz a sequência do passo-a-passo ali, você chega no ambiente E vai vim com aquilo na cabeça. . . Então eu vim com o passo-a-passo aqui, eu vou chegar passo a passo lá!

[5] **Original:** Principalmente no novato, eu acho que se isso tivesse acontecendo há mais tempo, acredito que o convívio com a parte real seria muito mais vantajosa, mas, digamos assim, flexível. . . Vamos falar assim. Que quando você sair, você tem esse contato, essa experiência no mundo virtual, você pega experiência e vai para o Real, vamos falar assim, vai ser bem melhor. . .

> virtual reality, for this reason, I think is extremely important... I think extremely important. [6]

Whereas the negative feeling towards the effectiveness factor can be seen in one interview excerpt:

> But if you consider the following way: you have to agree with me that it's not effective for the performing at the task itself, in the live line.[7]

The same criteria was adopted to the remaining dimensions in the UX framework. Every excerpt from the interviews in which the users discussed key factors and, more importantly, the way these factors were discussed was accounted for the determination of what the real score of each theme would be in the usability scale.

It is important to notice that in this context, the theme enumeration may not be as direct as in the case of a questionnaire, as the interviewees may oscillate between positive and negative aspects of the same theme, such as in the example below:

> This one, it has a great advantage, **if it's put to practice in the following way: You have to agree with me that it's not effective to perform the task itself in the live line**, but it is extremely important to review and recycle. [8]

In the previous excerpt from the interviews, the sentence in bold would be accounted for as a negative aspect of the effectiveness factor, even though it is between positive arguments of the same dimension. This shows how the use of a subjective questionnaires can provide more information per answer than an objective one.

Furthermore, this is an indication that the interviews can be searched for the occurrence of themes other than the predefined ones, or, that the interviews can provide more information than the initially observable. This observation leads to the investigation of any more themes that could be detected in the interviews and which additional information could be obtained in a broader analysis.

[6] **Original:** [...]mas ele é extremamente importante pra rever e fazer reciclagem. . .Fazer passo-a-passo de uma atividade que vai ser realizada. Rever o procedimento a tarefa, seguir aquele passo-a-passo, que a linha viva tem isso, E com esse ambiente virtual, praticasse com toda segurança e vai memorizar que na atividade tem essa sequência lógica a ser seguida. E esse programa de realidade virtual, para isso eu acho extremamente importante. . . eu acho extremamente importante!

[7] **Original:** [...]mas aplicados da seguinte forma: você tem que concordar comigo que ele não é efetivo para realização do trabalho em si de linha viva.

[8] **Original:** Esse aqui, tem um ganho muito grande, **mas aplicados da seguinte forma: você tem que concordar comigo que ele não é efetivo para realização do trabalho em si de linha viva**, mas ele é extremamente importante pra rever e fazer reciclagem. . .

6.2.3 Spontaneous Themes

For the analysis of spontaneous themes, the interview transcripts were scanned for the detection of sentences as for what the interviewee meant to say with those excerpts. The themes gathered from the excerpts were, then, accounted for and interpreted in the context of the speech of the interviewees.

In this case, the scanned themes were all regarding desires and expectations towards the virtual learning system focusing on verifying how the answers could indicate if the interviewees were satisfied with the virtual system function. This element is important in the sense of indicating how satisfactory the gameplay is for the user, specially in the efficiency dimension.

The efficiency of a system is defined in the UX framework as how well the system performs the user desires (ISO, 2018). In this context, the Aesthetics dimension of the MDA framework, which corresponds to the emotional sensation evoked on the player (HUNICKE; LEBLANC; ZUBEK, 2004), should allow for the creation of a learning experience that the learners are expecting.

It is important to notice that the learning experience is not the only one in the creation of a serious game, as there must be other factors as well. In the RV2 project, when detailing the virtual learning environment, it was defined that the system should also make the trainees feel challenged in order to avoid that the trainees delegate common activities to muscle memory.

To verify which was the experience the trainees had during the training session, the interview transcripts were scanned for additional themes, the organic themes, that showed how the trainees felt during the virtual experience. To gather these feelings, the interview transcripts had to be marked for the themes that the trainees mentioned and these themes had to be taken into consideration for mapping the expectations and outcomes experienced in the course of the interaction between the learner and the virtual environment.

The two main organic themes that were detected in the interviews were regarding feeling unsafe in the working environment and the necessity of memorizing the maintenance steps. These themes appear in the interviews from both groups – field maintenance professionals and non-field professionals – indicating the general feeling of the electrical maintenance professionals.

Examples of excerpts talking about feeling unsafe in the work environment taken from interviews from field maintenance professionals.

> [...] you are always apprehensive of the risk of coming near an energized

part, and the even more risks involved in the task.[9]

[...] when you're up there, it seems that the whole stuff is completely inadequate... Then you notice that even if it's inadequate you feel fine.[10]

Then, in the beginning, your attention is all in keeping yourself there... Kepping yourself safe... To place yourself... It's alldifferent, all... The smallest movement demands... Everything can go wrong, let's say.[11]

[...] The risk itself is something that prevents you from thinking properly. [...] [12]

Examples of excerpts talking about feeling unsafe in the work environment taken from interviews from non-field professionals.

[...] The thing is, on the live line you can't make a mistake. If you make a mistake you're done... We had an accident like this in Cascavel, and there was a death[...] [13]

But the activity itself demands a bit of attention, isn't it? This is the environment we live in, isn't it? Then, even if you know all the procedures, each of us feels the pressure to do it in the best possible way, isn't it? Avoiding the risks, isn't it? [14]

Examples of excerpts talking about the desire to learn and to experiment safely on the virtual system taken from interviews from field maintenance professionals.

9 **Original:** "[...]você fica muito apreensivo com risco de se aproximar de uma parte energizada e os riscos da atividade[...]

10 **Original:** "[...]Quando você chegar lá em cima, parece que é um troço completamente inadequado... Depois, você nota que ele continua inadequado mas, você está se sentindo bem[...]

11 **Original:** "[...]Então, nesse começo, a sua atenção está em se manter ali. . .Se manter seguro. . .Se localizar. . . Tudo difícil, tudo é. . . O mínimo Movimento exige... da tudo errado, digamos assim![...]

12 **Original:** "[...]Então tem oportunidade você repetir melhor serviço que você está fazendo. O próprio risco é uma coisa que impede você de refletir bem. . . [...]

13 **Original:** "[...] Que linha viva você não pode errar. Se você errar, você já... Tivemos acidente em Cascavel aí que houve fatalidade.[...]

14 **Original:** [...] Mas a própria atividade requer um pouco de atenção, né? Que é o meio que a gente vive, né? Então, mesmo você sabendo todo o processo, cada um tem a cobrança para fazer da melhor maneira né? Evitando os riscos, né?[...]

> I think it helps a lot, it's hard for one, working day by day like this, to remember the steps... Like recycling, like... And, specially, to revise the procedures before you start doing the maintenance. [15]
>
> [...] Like I said in the interview, when you do the sequence of the step-by-step there, you get to the real environment and you have that in your mind... Then, as I had the step-by-step here I'll follow the step-by-step there! [...][16]
>
> [...] That when you do things right you don't get tired, you don't have the problem of stress, if you make mistakes too often you get stressed with that, with the work you can't manage to do right [17]

Examples of excerpts talking about the desire to learn and to experiment safely on the virtual system taken from interviews from non-field maintenance professionals.

> There are a lot of tasks, it is an enormous list of tasks. And sometimes it's too difficult to memorize everything just reading from a book. It's also difficult for the guy to be in the real environment, and having to do all those tasks, considering the problems of shutdown procedures and the difficulties for personal displacement. [18]
>
> Actually, the fact that you perform a task and you see it from the beginning through the end, I believe this will make you... One task is the consequence of the other [19]

Hence, to allow for the trainees to have a positive experience, these reported necessities should be addressed and satisfied in a manner which should allow for them to feel that the virtual environment has enabled them to achieve the results they

---

[15] **Original:** "[...]Acho que ajuda bastante, pega pra gente que trabalha no dia dia assim, para relembrar os paessos... Como uma reciclagem assim. . . E, principalmente, pra relembrar o procedimento antes de fazer a manutenção.

[16] **Original:** "[...]Foi como eu falei na entrevista ele, quando você faz a sequência do passo-a-passo ali, você chega no ambiente E vai vim com aquilo na cabeça. . . Então eu vim com o passo-a-passo aqui, eu vou chegar passo a passo lá![...]

[17] **Original:** "[...]Que quando você faz certinho você não cansa, você não tem um problema de estar estressado, você erra muito e você começa ficar estressado com aquilo lá, com aquele serviço que não está dando certo.

[18] **Original:** "Tem muitas tarefas, é um rol muito grande de tarefas. E às vezes é difícil de memorizar só lendo em um livro. E igualmente é difícil o cara estar no ambiente real e tendo que fazer todas aquelas tarefas, até por questões de desligamentos, dificuldade de deslocamento.

[19] **Original:** "Mas, a questão de você executar uma tarefa e ter um início e um fim, eu acho que isso vai gerando... Um serviço é consequencia do outro e isso acaba gerando né...[...]

personally expected. To assert if these expectations were met, the transcripts were scanned for the complementary themes in order to verify if they occurred in an organic form.

In the case of these themes, the counterpart of the themes was created, as shown in table 7. The counterpart themes were found in the interviews, however, if the themes did not occur organically, the next step would be to scan the interview transcripts for them.

TABLE 7 – Organic themes and their counterparts.

Organic theme	**Theme counterpart**
Unsafe working conditions	Training for safer working conditions
Memorization of training steps	Training for practising steps

Examples of the occurrence of the training for safer working conditions, that occurred in the interviews from field maintenance personnel.

> [...] you will be more used to it from the start, even if it’s a recycling course or a pre-training course. And from the beginning you’ll feel more comfortable with the risks of the activity itself. [20]

> You get the task, you can simulate it as a real life task, and you could cover all the risks there, isn’t it? To avoid an accident... Because this way the person can get used to the task. [21]

> Within this virtual environment, practice happens safely and one will memorize the fact that there is this logical sequence that has to be followed throughout the whole activity [22]

Examples of the occurrence of the training for safer working conditions, that occurred in the interviews from non-field maintenance personnel:

> The greatest advantage is that you’re not running risks, as in real life. This is the greatest benefit. Especially when you’re working with live line. The thing is, on the live line you can’t make a mistake. If you make a mistake you’re

[20] **Original:** [...] vai chegar mais habituado, nem que seja uma reciclagem e pré treinamento e já vai chegar mais habituados riscos da atividade em si.

[21] **Original:** [...] você vai pegar as atividades vai poder simular uma atividade real e, cerca todos os riscos ali, né? Pra evitar um acidente [...]. Porque assim também, a pessoa pode ficar mais habituada à atividade.

[22] **Original:** E com esse ambiente virtual, pratica-se com toda segurança e vai memorizar que na atividade tem essa sequência lógica a ser seguida.

> done... We had an accident like this in Cascavel, and there was a death[...] [23]
>
> I believe that this way, the benefit is that when you have this virtual training, you're not so much exposed to risks, isn't it?[24]
>
> Ah, one of the benefits, which I think is the most important, is the fact that you feel as if you're in real life, but you'll be actually not near any risk.[25]

Examples of the occurrence of the training for safer working conditions, that occurred in the interviews from field maintenance personnel.

> I think, as I said before, I think it's more like to learn the right position for the person, to know the weight of the equipment, the smallest details[26]
>
> As I told him in the interview, when you follow the sequence step-by-step there, then you get to like real life environment and you have everything in your mind... Then as I do step-by-step here I'll go step-by-step there[27]
>
> I believe it helps a lot, the way you work day by day, it's hard to remember the steps. It works like recycling or so... And mainly to retrace the proceedings before you do the maintenance work. [28]

Examples of the occurrence of the training for safer working conditions, that occurred in the interviews from non-field maintenance personnel.

> There are a lot of tasks, a wide variety of tasks. And sometimes it's difficult to memorize everything if you just read it in a book. It's also difficult for the guy to be there in the real environment, and having to be perform all those

[23] **Original:** O benefício é que você não se expõe na área de risco. Esse é o maior benefício. Principalmente na linha viva! Que linha viva você não pode errar. Se você errar, você já... Tivemos acidente em Cascavel aí que houve fatalidade.

[24] **Original:** Eu acho que assim, benefício, que quando você faz o treinamento virtual você tem uma menor exposição ao risco, né?

[25] **Original:** Ah, um dos benefícios, que eu acho um dos mais válidos, é a questão de que vai tar na vida real, mas tipo você vai tar longe do risco.

[26] **Original:** Eu acho, que como eu disse, acho que é mais usar a questão de posicionamento da pessoa, de saber o peso que são os equipamentos, os detalhes mais minuciosos asim. . .

[27] **Original:** Foi como eu falei na entrevista ele, quando você faz a sequência do passo-a-passo ali, você chega no ambiente E vai vim com aquilo na cabeça. . . Então eu vim com o passo-a-passo aqui, eu vou chegar passo a passo lá!

[28] **Original:** Acho que ajuda bastante, pega pra gente que trabalha no dia dia assim, para relembrar os passos... Como uma reciclagem assim. . . E, principalmente, pra relembrar o procedimento antes de fazer a manutenção.

> tasks even if you take into account the shutdown procedures, the difficulties for personnel displacement. [29]
>
> Actually, the fact that you perform a task and you see it from the beginning through the end, I believe this will make you... One task is the consequence of the other. [30]

In these excerpts, it is possible to notice that the interviewees could express what they expected from the training environment, showing what would be valuable to them in the training process and which features would add value to them in a system designed to enhance the instructional process. This information can be used in future development of the project and in the upcoming versions as to how to conceive further functionalities and which features could be valuable, or not, for the trainees.

This analysis allowed to assert what the perception of the trainees is regarding how they felt while interacting with the serious game and what would be the feeling they expected. Hence, the thematic analysis aided to reveal what was happening in the Aesthetics layer of the MDA framework of the virtual environment, as this layer treats the process occurring within the player's mind during the gameplay and within the learner's mind as learning takes place.

6.3 CONNECTING THE MDA FRAMEWORK AND GAGNÉ'S THEORY

This chapter showed initially how Gagné's instructional design was used in the creation of the rules of the game and in the gameplay development as well, which, in turn, corresponded to the Mechanics of the MDA model. It is possible to make such assertion as the definition of the game rules coincided with the learning objectives, showing how these two elements correlate to each other.

The instructional design activity was shared between the game developer and the maintenance instructor, allowing for the game rules to be embedded in the rules of the business, as defined by software engineering theory. This process happens in the instructional design part of the software development, in which the game functioning should be defined.

In the player side of the virtual learning system, by analysing the themes present in the interviews, it was possible to assess how the learning process occurred and how the trainees felt about it. This process evidenced the Aesthetics layer of the

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[29] **Original:** Tem muitas tarefas, é um rol muito grande de tarefas. E às vezes é difícil de memorizar só lendo em um livro. E igualmente é difícil o cara estar no ambiente real e tendo que fazer todas aquelas tarefas, até por questões de desligamentos, dificuldade de deslocamento.

[30] **Original:** Mas, a questão de você executar uma tarefa e ter um início e um fim, eu acho que isso vai gerando... Um serviço é consequencia do outro [...]

MDA framework and allowed it to be connected to Gagné's instructional events, more specifically, the following events selected from table 1:

- 2 - Informing learner of the objective;
- 4 - Presenting the stimulus material;
- 5 - Providing learning guidance ;
- 7 - Providing feedback about performance correctness;
- 9 - Enhancing retention and transfer.

In conclusion, these experiments showed that the creation of a connection between Gagné's Instructional Events and the MDA framework, outlining how serious games relate to modern game design frameworks and pedagogical models, showing that it is possible to analyze in a unique manner the serious game and game design aspects of the learning system. These elements create the backbone of a unified analysis for the pedagogical and game design theory.

7 DISCUSSION

In the previous chapters, the research definitions and data gathering strategy are detailed. With the definition of the initial concepts and the data gathering procedure, the data processing and results from the interviews could be created to detect trends and allow to draw conclusions regarding the data captured.

To allow for the creation of a complete landscape regarding the system development process, the results from both the initial development steps and the final trainee training interviews were compiled. The data from these development aspects got analysed through techniques to provide information and insight regarding the trainee's opinions and feelings.

In order to validate the procedure, it is necessary to extract metrics based on the themes and codes present in the interviews so as to allow for the analysis of data and comparison to the traditional questionnaire method. Hence, initially, we defined metrics allowing for the interpretation of the results in a manner that is compatible to the UX traditional assessment.

After the metrics were defined, the interview was interpreted in accordance to each metric defined and afterwards the results were compared to the traditional Likert-Scale questionnaire.By comparing both artefacts, the interview interpreted by our method and the traditional questionnaire method, the similarities and the differences were shown and the final results compared in order to determine points in which the proposed method could be improved and which problems present in the traditional method are solved by the proposed method.

In section 7.1, the metrics used for the analysis of the interviews is presented and the main concepts regarding UX theory and how the metrics were accounted for. This lays the foundation to the analysis of the interviews and how the themes should be accounted, as well as why themes were chosen to process the interview transcripts.

Section 7.2 describes how thematic analysis is utilized to gather data from the interview transcripts. The section is divided in two, corresponding to the analysis based on the predefined themes, defined a priori by the analyst, and organic themes, gathered from the interviews.

Finally, section 7.3 details the manner in which the rules of the game were defined using both instructional design and game design. These elements detailed the definition of how the virtual learning system should function and which are the success and failure conditions for the defined training activity.

7.1 METRICS FOR INTERVIEW ANALYSIS

During the development of the virtual learning system, the developers consider the desired functionalities based on a list of desired operations and functions that the system should have. However, the degree of success achieved by the developed system cannot be fully appreciated until the intended audience share their experiences.

In the case of the developed virtual environment, the effectiveness of the instruction was the main factor to take into consideration, both on the part of the instructor as well as on the part of the trainee. These two actors have complementary interests; the instructor intends to include a training scenario in the system, whereas the trainee needs to fetch the training scenarios stored in the system.

To assert if the developed serious game was effective for both sides, their experiences had to be asserted and the data regarding those interactions had to be accounted. The effectiveness metrics should take into consideration the individual interests of the involved parties, so that the involved actors could be heard and the data assessed.

The traditional UX measurement questionnaire is composed of a set of Likert-Scale questions designed to determine how the user feels towards a system and provide a score to the system in order to both guide the development of the system and make it possible to compare two different systems. In this case, the virtual training environment can be compared to the traditional training methodology.

However, unlike the Likert-Scale questionnaire, the semi-structured interview has no objective scores which can be accounted and compared. Hence, the interview data must be compatible to the traditional questionnaire. Furthermore, our analysis contemplates both the subjects defined in traditional UX questionnaires and the organic themes mentioned by the interviewee, which must be accounted for in an extended analysis.

In order to do so, we have defined three metrics and compared them to the classical UX questionnaire to allow for the comparison of data between interviews:

1. The number of times the item was mentioned during the interview, showing how often the interviewee returned to a determined theme during the interview. It indicates how often the subject has been remembered, calculated by the raw number of times the interviewee talked about a subject during the course of the interview;

2. Percentage of the text in which a single theme appears. This is expressed by a percentage calculated by the ratio between the word count regarding one single theme and the whole text;

3. How widely in the interview the theme is present. This metric is calculated by calculating the difference between the last and first times the theme was mentioned in the interview.

These techniques are all based in the recurrence of the themes in the interview, in much the same manner in which the recurrence of words is evaluated in the word cloud methodology (SELLARS; SHERROD; CHAPPEL-AIKEN, 2018). This qualitative analysis method is used to create metrics from the interview text, for determining how many times and how often the interviewee speaks about a theme, and how long during the interview the theme was present in the interview.

Despite sharing the same theoretical basis as the word cloud technique, grouping by themes is a strategy to provide context regarding the interview texts and to interpret how the interviewee experiences the virtual environment. For comparison purposes, the word cloud generated by one of the interview is shown in figure 24. In this figure, it is possible to notice which words are most often used by the interviewee.

FIGURE 24 – Word cloud representing the interview, in this diagram the size of the word is defined by how many times a word was mentioned. Source: Elaborated by the author.

It is important to verify that the most evident words in the cloud do not give any clues regarding which are the most important features of the virtual environment to the trainee. To mitigate this issue, the word cloud might be replaced by a tag cloud, in which the tags are the usability dimensions.

However, in order to allow for the comparison to the established UX theory, the word cloud fails to produce usable data, as the UX theory needs to map Pragmatic and Hedonic qualities as well as Attractiveness in order to describe the system. The word cloud, however, does not produce numeric scores to allow for this comparison. Hence, it is necessary to create other means of accounting for the scores.

7.2 THEMATIC ANALYSIS

The analysis of themes is a cornerstone of the proposed method, as it allows an analyst to define what is the motivation for the user to engage with the learning process in the virtual environment. This information is specially important to allow for the maintenance and future development of the virtual learning environment, as it s possible to understand what expectations the trainees have and plan on how to meet them.

In this work, the analysis is presented in the form of predefined themes and organic themes, these two approaches were chosen in order to evaluate not only the information that was determined a priori, but to discover information that was important to the trainees as well. Each of the data has a distinct and vital importance: the former information is important to evaluate the development performed up to the release of the virtual environment to the audience, while the latter evidences what is necessary for the continued development, to keep track of the features and functionalities important to the trainees.

As the needed information regarding the developed system was how the trainees felt when they used the system, the predefined themes chosen were the UX dimensions. The information was analysed in a number of manners, showing various aspects of the data and allowing for a conclusion to be reached on how effective the trainees felt that the system is.

In contrast, when analysing the organic themes, it was possible to verify the expectations the trainees had for the system and if they were met. By analysing themes other than the predefined ones, it was possible to acknowledge the experience the trainees had on the system and to validate that in the design process.

Thus, by making these analyses, the development could be evaluated, both by comparing the answers to a predefined framework and by adding new information to the analysis. This process, then, welcomes the trainee experience as a feature in the development process, making sure that the development process does not stray from the path that adds most value to the intended audience.

7.2.1 Predefined Themes

To analyse the data from the interview, charts for the defined metrics were elaborated. Initially, the percentage of the words of the text that relate to one theme. The values are detailed in table 8 and is shown in figures 25 and 26.

TABLE 8 – % of words by theme in the interview

Theme	Quality	Value
Attractiveness	Pure Valence	5.13
Perspicuity	Pragmatic	6.84
Efficiency		20.39
Dependability		3.30
Pragmatic score		10.18
Stimulation	Hedonic	2.36
Novelty		11.05
Hedonic score		6.71

In table 8, it is possible to notice how the interviewee gives focus to the Efficiency and the Novelty of the system, which are in turn one pragmatic and one hedonic quality of the system. In this case, the result reflects how much of the text the interviewee dedicated to a single theme, calculated by how many words related to a theme were in the interview divided by the number of words in the text.

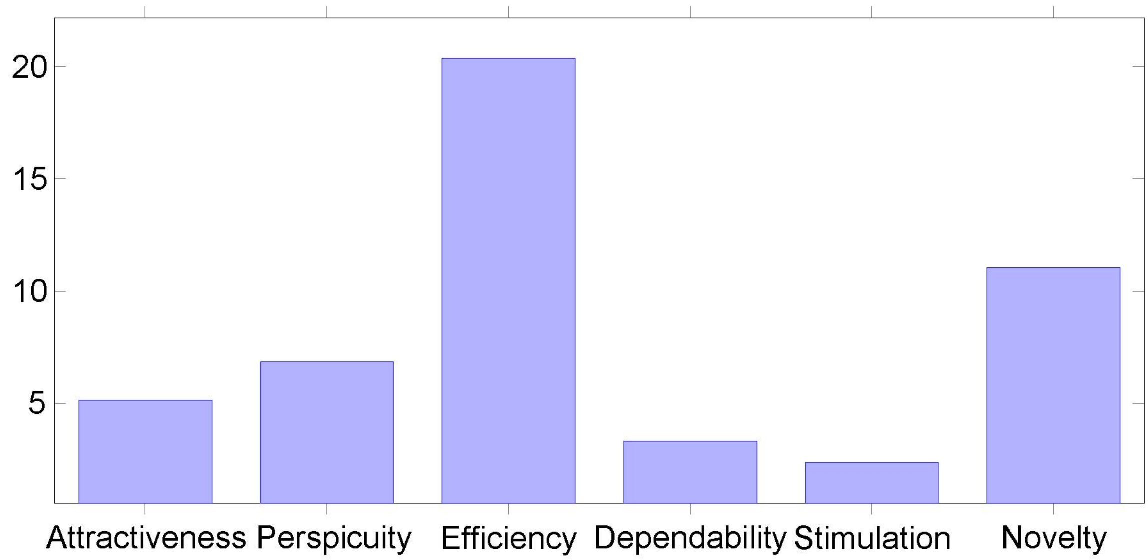

FIGURE 25 – The percentage of the text covered in each theme. Source: Elaborated by the author.

Figure 25 shows that by using the themes, it is possible to get metrics more aligned to the traditional User Experience Questionnaire. However, unlike the traditional UEQ, the score of each dimension is not constrained to the interval between -3 and 3.

To allow for the interpretation of metrics in both the positive and negative aspects of each usability dimension, the number of words used to describe positively and negatively each aspect were accounted and then subtracted the negative mentions from the positive ones.

This result shows that the interviewee have stronger feeling towards the Efficiency and Novelty metrics of the virtual environment. This is reinforced by the fact that the interviewee frequently mentioned how the field activities involved much more tools and personnel than in the virtual environment and how that was a novel take on the training activity.

Continuing the analysis in a similar manner than the defined by the UEQ bibliography, the Pragmatic and Hedonic qualities were obtained by calculating the average between Perspicuity, Efficiency and Dependability for the Pragmatic Qualities and Stimulation and Novelty for the Hedonic Qualities. The results are shown in figure 26.

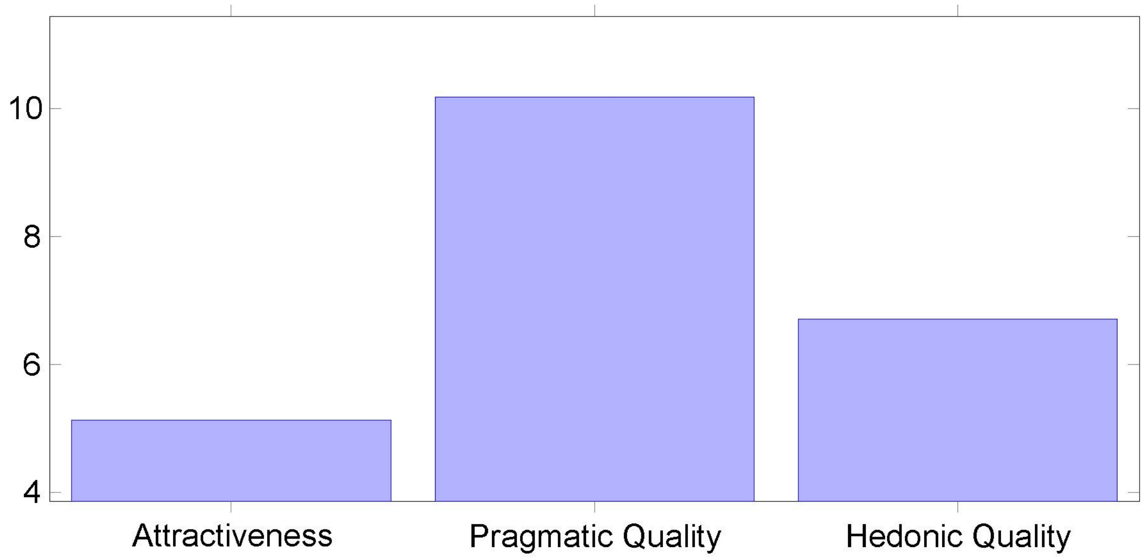

FIGURE 26 – Pragmatic and Hedonic qualities calculated by the percentage of the text dedicated to each theme. Source: Elaborated by the author.

It is possible to perceive how the Efficiency score affected the overall calculations and made the Pragmatic Quality the highest metric. Hence, by this manner of interpreting data, the interviewee feels that the system has a much stronger practical purpose than the fact that it is enjoyable to interact with. However, this does not mean that the virtual environment is unattractive; the attractiveness score is still higher than the Hedonic Quality, even though it is closer to the Hedonic quality score than to the Pragmatic Quality score.

Afterwards, the same analysis was performed counting how often a theme was mentioned in the interview. In this method, the amount of text the interviewee dedicated to a theme was not considered, just the number of times the interviewee cited the theme in the interview. The values are detailed in table 9.

It is interesting to notice that the interview was devised in order to have one question for each theme, which did not guarantee that the interviewee answered each question within the defined theme, which caused the variation of times each theme was mentioned. The chart showing such data is shown in figure 27.

In this chart, it is possible to perceive that the number of times a theme was mentioned is much more consistent across themes than the word count, it did not

TABLE 9 – Number of times the theme was mentioned in the interview

Theme	Quality	Value
Attractiveness	Pure Valence	5
Perspicuity	Pragmatic	1
Efficiency		8
Dependability		3
Pragmatic score		4
Stimulation	Hedonic	3
Novelty		3
Hedonic score		3

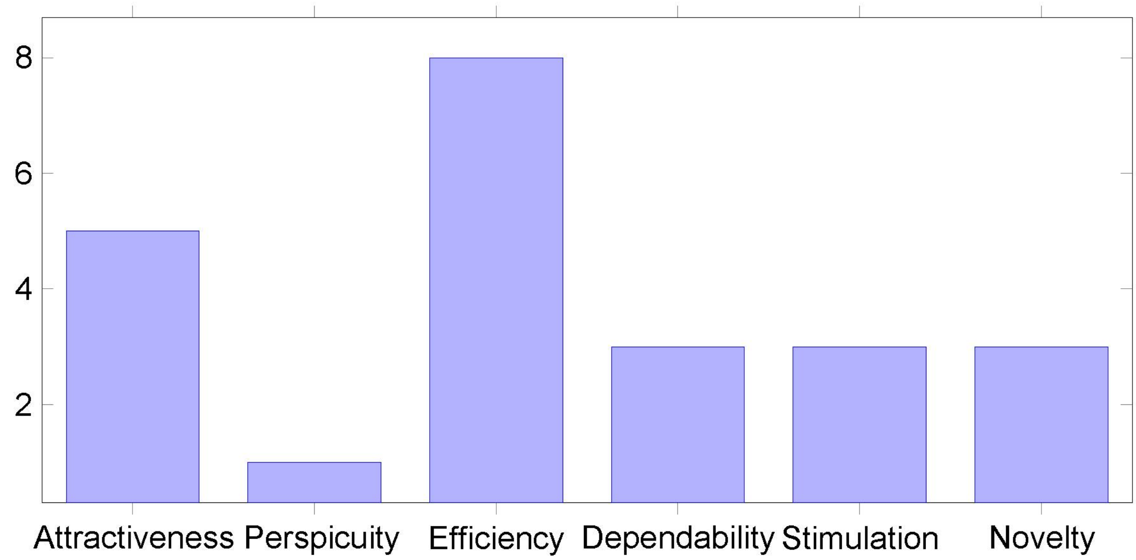

FIGURE 27 – Histogram representing the quantity of times each theme is mentioned in the interview. Source: Elaborated by the author.

produce any value far too greater than the others and kept itself nearer to the range between -3 and +3. When calculating the Pragmatic and Hedonic qualities, the averages of the values kept the consistency with the conclusions shown in figure 28.

Using this metric, the ranking of Pragmatic Qualities, Attractiveness and Hedonic Qualities are maintained from the chart shown in figure 26. However, the scores differ in the manner that the difference between Pragmatic Quality and Attractiveness is smaller and the difference between Attractiveness and Hedonic Quality is greater than the previous analysis.

The Pragmatic Quality is still the leading score, again determined by the score in Efficiency, which was mentioned more than any other UX dimension in the interview. This score, however, is consistent with the previous analysis, in which Efficiency was highlighted as the leading UX factor of the virtual environment.

Afterwards, the metric used to analyze the interview was how widely a theme was present in the interview. This score was calculated by the difference between the position of last letter of the last mention of the theme in the interview and the position

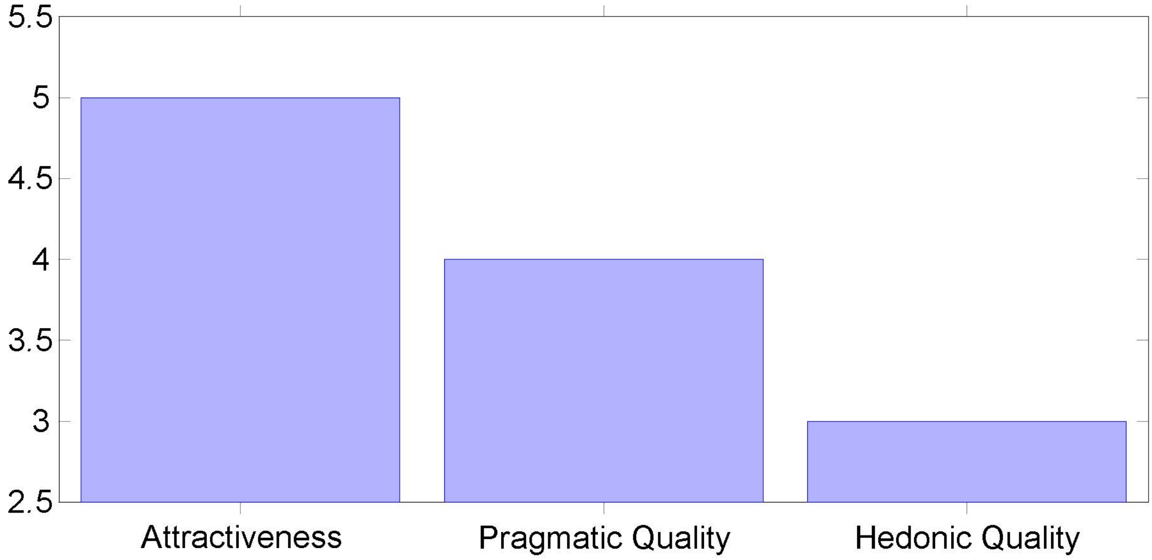

FIGURE 28 – Pragmatic and Hedonic qualities based in the quantity of times each theme is mentioned in the interview. Source: Elaborated by the author.

TABLE 10 – How widely the theme is present in the interview

Theme	Quality	Value
Attractiveness	Pure Valence	11.95
Perspicuity Efficiency Dependability	Pragmatic	4.81 76.83 21.99
Pragmatic score		34.54
Stimulation Novelty	Hedonic	4.21 77.43
Hedonic score		40.82

of the first letter of the same theme in the interview. This score reflects how long the theme was present in the interview, as the interviewee does not always limit the themes in the answers to the questioned theme. The scores are shown in table 10.

To allow further analysis, the corresponding chart is shown in figure 29.

It is possible to notice in these charts that the two initial and final themes present in the interviewee discourse were Efficiency, such as in the other metrics, and Novelty. It is interesting to notice that both Pragmatic and Hedonic qualities presented one of the themes with the highest score. The Novelty theme is the leading Hedonic quality in both figures 25 and 29, despite the fact that in the latter figure Novelty has the same magnitude as Efficiency – the general leading UX theme in the previous analyses.

This theme diversion created a different chart showing the UX qualities, as shown in figure 30.

Through this metric, the virtual environment Hedonic Quality became the highest scoring metric, not the Pragmatic Quality as in the previous measurements. This is caused as the Hedonic Quality is calculated by the average between two dimensions

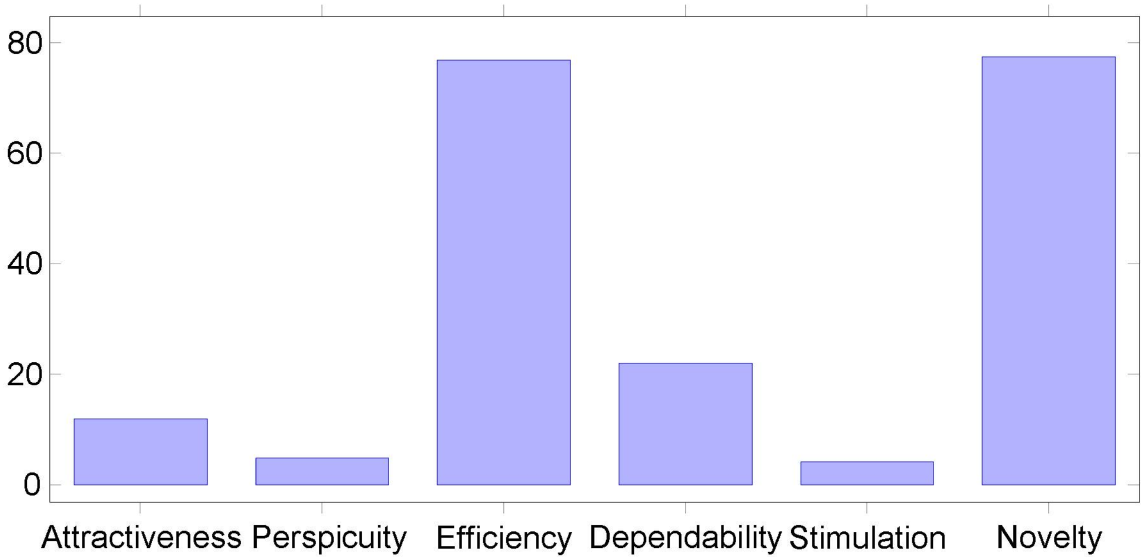

FIGURE 29 – Histogram showing how widely distributed in the interview each theme is. Source: Elaborated by the author.

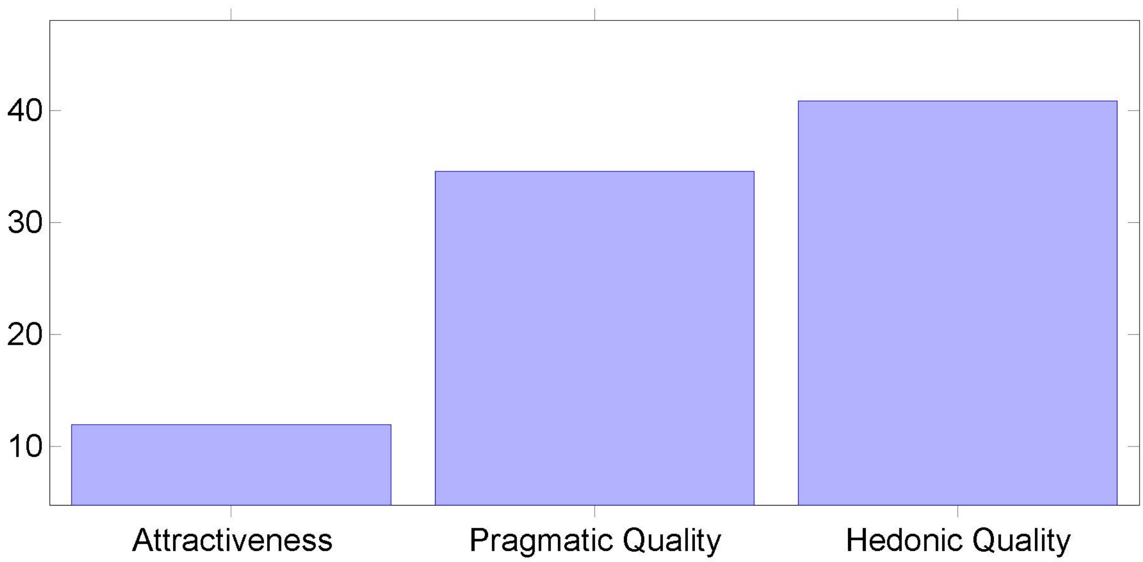

FIGURE 30 – Pragmatic and Hedonic qualities based on how widely distributed in the interview each theme is. Source: Elaborated by the author.

– stimulation and novelty – and the Pragmatic Quality is calculated by the average of three scores – Perspicuity, Efficiency and Dependability. As the difference of the top scoring metrics and the others has attenuated the Pragmatic Quality score; in this case, Perspicuity and Stimulation have irrelevant scores, which caused the Efficiency score to be divided by three and the Novelty score to be divided by two.

For comparison, a different training specialist was asked to answer a traditional User Experience Questionnaire. The scores computed are shown in figures 31 and 32.

These charts show that by the traditional interview method, the defining characteristic of the virtual environment is the novelty and the characteristic that scored the least was perspicuity. It is necessary to notice that the UEQ produced no negative

TABLE 11 – How widely the theme is present in the interview

Theme	Quality	Value
Attractiveness	Pure Valence	1.833
Perspicuity	Pragmatic	1.250
Efficiency		2.000
Dependability		2.000
Pragmatic score		1.750
Stimulation	Hedonic	2.000
Novelty		2.500
Hedonic score		2.250

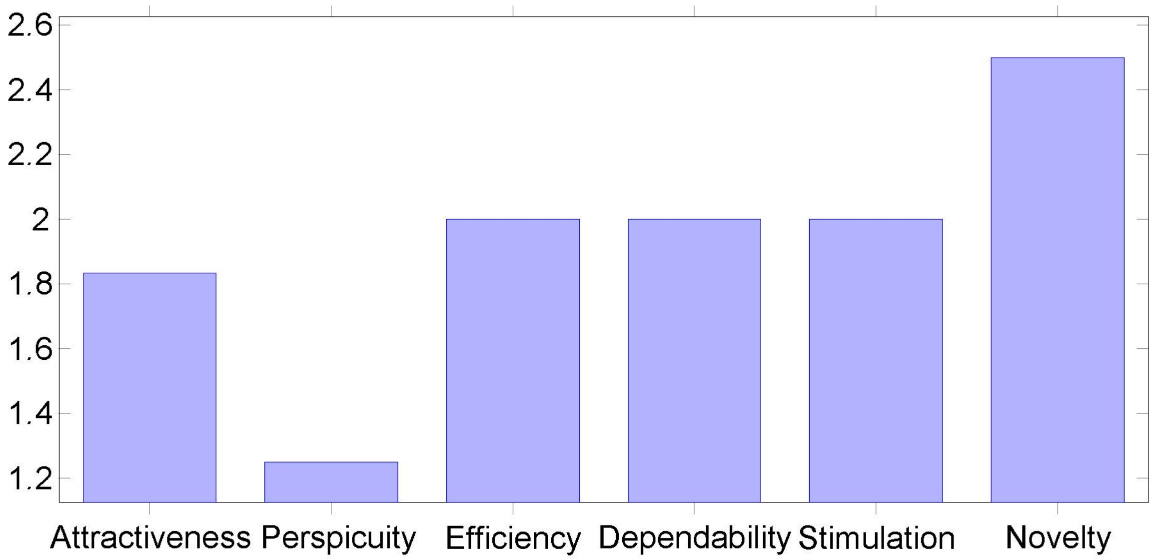

FIGURE 31 – User Experience dimensions according to the traditional User Experience Questionnaire. Source: Elaborated by the author.

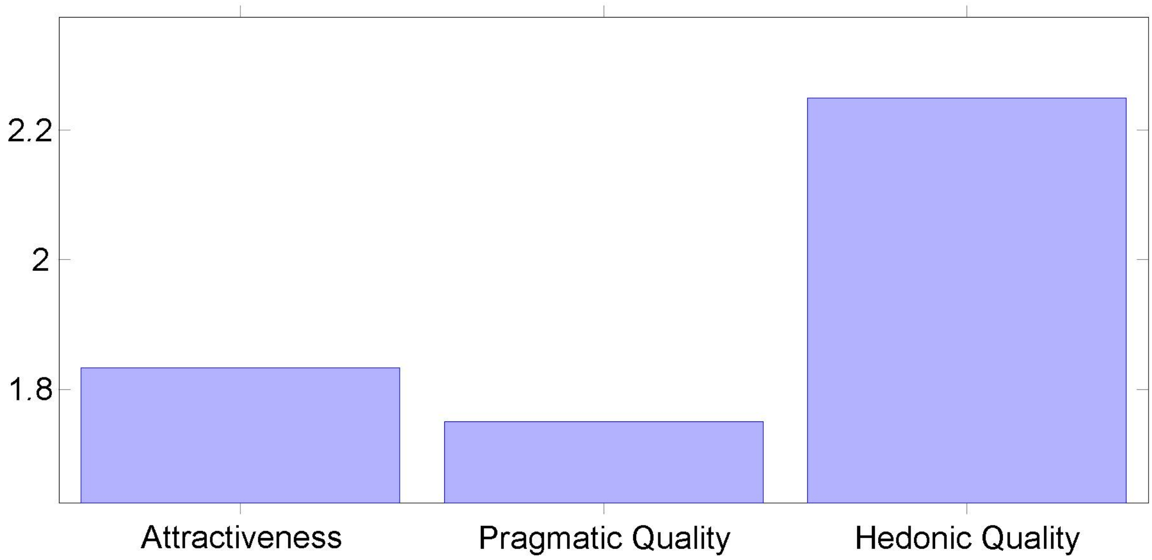

FIGURE 32 – Pragmatic and Hedonic dimensions according to the traditional User Experience Questionnaire. Source: Elaborated by the author.

results, which shows that the interviewee has a positive feeling towards the virtual training environment.

The results from figure 31 confirm the results from figure 27 and 29 that perspicuity is the least scoring characteristic. Furthermore, the Novelty score from figure 29 is also reinforced.

It is interesting to notice how the perspicuity metric is the one that has the lowest score. It indicates that the process needs to be improved in this aspect, either by system design or by exposing the trainee further to the virtual environment and guaranteeing that they become more familiar to the Virtual Reality hardware.

The differences between interviews are also important to the observed. Initially, it is possible to notice how both figures 31 and figure 27 show similar figures, in which there is a predominant characteristic – either Efficiency or Novelty – reported by the interviewee. Each interviewee has picked one favourite characteristic of the virtual environment depending on their professional profile.

7.2.2 Organic Themes

Differently from the traditional User Experience Questionnaire, that does not allow for the creation of other metrics, different from the ones devised for the questionnaire per se, the semi structured interview can be used to map such themes. As the purpose is to evaluate the next steps in the development of the virtual environment, it is possible to harvest more data regarding the expectations of the trainees for the system functionalities.

This part is specially important, as usefulness is a metric taken in consideration during the evaluation of User Experience; the quality of the system is based on how useful it is to the user. To assert these themes, the interview was re-evaluated and relevant parts of the interview were coded according to what the interviewee expressed. The themes listed in this manner are shown in table 7.

Without going into further analysis at this moment, the themes reveal the opinion of the interviewee regarding the activity itself, that the activity is complex and requires the memorization of steps, as well as it is conducted in a complex, uncomfortable and unsafe environment. Furthermore, the complexity is relative to both the procedure itself and to the equipment necessary to conduct the maintenance activity.

However, to establish a development plan in order to create a complete view on the training process and the development of the virtual environment, the trainees opinions must be taken into consideration. In order to do so, the theme occurrence metric is used in order to account for how much the themes have been mentioned in the interview. The result is shown in figure 33.

In the chart, the occurrence of themes is not limited to the virtual environment or to the real environment, but depending on the nature of the feedback, it is possible

FIGURE 33 – Histogram of the total times the organic themes mentioned by the interviewees.
Source: Elaborated by the author.

to understand how the interviewee perceives the whole process. By interpreting the data shown in figure 33 and by verifying the cultural background of the interviewee, it is possible to create a more comprehensive interpretation of data.

Initially, it is necessary to notice that the interviewees are professionals who work for the electrical company and who have contact with the real-life maintenance environment, even though not all have field experience, as some work as control room operators and off-site maintenance personnel. The focus of the interviewee is more on the practical questions of the training activity and the whole maintenance process as a whole.

It is possible to notice on figure 33 that the most present theme in the interview revolves around how unsafe the procedure is, as the technicians work in a hazardous environment. The need to remember the steps come in a second place, as the main concern of the professionals.

The theme related to steps memorization, evidences that the virtual environment introduces a simplification in the training procedure regarding how it helps the trainees to remember the steps. It is interesting to notice how the most cited themes regarding the virtual and real environments are complementary to each other, meaning that the virtual environment is meeting the expectations in simplifying the training process in the optics of the trainee.

The purpose of User Experience evaluation is to guide further development of the system, and one of the requisites for a good User Experience according to the ISO is how useful a system is to a user. In this matter, it is possible to notice the system to have a high usefulness which is to simplify the process for the trainee to learn and to create a safer environment for learning.

7.3 LEARNING AND GAME DESIGN

In the context of serious games, the game design theory must be allied to a pedagogical model in order to allow for the construction of a complete framework that can address the creation of an efficient virtual learning system, one that allows for trainees to practise the activities they desire and enhance their abilities.

7.3.1 Instructional Design of Professional Activities

To assert whether the instructional design was effective in the creation of training scenarios, the instructors were interviewed and the system was judged in the interest of verifying the accuracy of the above mentioned training scenario. This was done in order to allow for the validation of the virtual environment.

In the case of the virtual learning environment developed in the context of the project, the instructional design and the software design were performed in the same stage, fused in a single stage and in a single activity. This is not a desired modelling feature, as the intention was to allow for the instructors to create their own training scenarios and not for them to work along with the system developers.

However, in this case, the instructor verification of the virtual environment was part of the development process, taking part on how the developers asserted the correctness of the developed system. The hard coded activity and the associated tools were developed in the context of the system development and were validated at the end of the development process.

During the development process, the instructors validated the virtual system. This allowed for tests with the trainees and the posterior data acquisition regarding the user experience and the verification of the learning process as well.

In conclusion, in the case of the virtual learning environment, the instructional design was performed as a part of the system development. Hence, the instructional design was validated along with the developed system for the implementation itself to move forward.

7.3.2 Game Design of Professional Activities

This section details how the game design theory contributed to the learning environment and how the elements were incorporated to the creation of an immersive learning environment. Although some aspects were intrinsic to the system and its architecture, others needed to be designed and included in the system for enhancing the player experience.

One of the guidelines for the creation of the virtual environment for live line electricians training was that the environment should encourage the trainees to experiment and retry as much as possible, to motivate the trainee to repeat the training activities as often as possible. To address this requirement, serious games techniques were used in the interaction design of the system.

To achieve the desired result for the user experience, game design concepts were used to create the interaction of the system. The concepts were already discussed in Chapter 2, so, this section will discuss how the concepts were implemented in the virtual environment.

Huizinga's Magic Circle is a concept that relates to the fact that a game world should be conceptually apart from the real world. This concepts translates to virtual reality in a straightforward manner, as the system is designed to replace the reality in which the players find themselves with a synthesized one, in this case, created by computer rendering techniques.

Another theory used as means of motivating the trainee to interact further with the virtual environment was the PENS (Player Experience Needs Satisfaction) (SCOTT RIGBY, 2011). This theory states that, during the interaction with a game, players expect three needs to be satisfied: 1. Autonomy; 2. Relatedness and 3. Competence.

According to this theory, the game is a medium through which the player freely exercises decision making (the need for Autonomy), the creation of relationships (the need for Relatedness) and the capacity of overcoming challenges (the need for Competence).

These needs may be translated in learning terms, as the need for Competence is related to the learning activity per se and it is related to the satisfaction a learner gets from being able to overcome a new challenge, which is equivalent to learning a new skill. It is necessary for the trainees to feel that they have evolved in the context of an activity and verify what they have learned in the process.

The Magic Circle created in this manner is not only a conceptual construct, it is a real world limitation that must be observed. However, as the creation of such an environment isolates the trainee from the real world, the social interactions become equally limited. It is important to bear in mind that the creation of multiplayer virtual scenarios is possible; it is just outside of the scope of the current project.

To better understand the trainees and how to motivate them, the PENS theory was used in order to provide a framework to describe how to address the trainee's motivational process. This theory maps three needs that players expect a game to address: 1. The Need for Competence; 2. The Need for Autonomy and 3. The Need for Socialization.

The Need for Competence relates to the need to master a challenge presented to the player. This need is based in the need to overcome difficulties.

For the system to fulfill its purpose the flow theory (CSIKSZENTMIHALYI, 1990) and the PENS theory (SCOTT RIGBY, 2011) must be analyzed together as they both address the motivation issue, making both theories complementary in the current context.

Regarding the aspect of challenge and overcoming difficulties, both the PENS and the Flow theory address the issue, however, they both view it in a diverse manner. The Flow theory focuses on the challenge progression and how the challenge perceived by the player influences in the motivation. According to the Flow theory, given that the player feels immersed in the game, the challenge must contribute to keep the player invested in the activity through challenge progression.

The PENS theory, however, states that the players have a necessity to overcome challenges and feel that they have mastered such challenges. To satisfy this need, the players must feel – as stated by the Flow theory – that they are not underwhelmed neither overwhelmed by the challenge presented to them.

Although both theories address the issue of challenges and how a practitioner interacts with them, the Flow Theory aims to provide a manner in which to keep the practitioner interested in a given challenge. This does not disregard the subjective component of the practitioner's personality; it does not aim to interest subjects in an activity, but to not lose interest in which the subjects are already interested.

The instructional design was used in the development of the virtual environment for mapping all the maintenance tools and maintenance processes. During this process, the elements of the virtual environment were discriminated in order to be subsequently modelled and have their behaviour programmed in order to create interactions as close to the real objects as possible.

This shows that the definition of the learning steps can be aligned with the definition of game rules, in which case, the instructional design can be seen as part of the Mechanics element of the MDA framework, as it is, in final analysis, part of the player experience design. In this case a change of the MDA framework diagram could be proposed, as shown in figure 34.

While creating the learning experience, the instructional designer is, in his own manner, defining some of the game world rules, and helping shape the player/learner experience. So, then, the creation of such a framework has direct impact on the production of game learning environments. Under this lens, the focus on the content itself should be taught along with the definition of the game mechanics.

The learners, though, are the active actors in the learning process, as what they experience is the driving force of the transformation, much in the same manner

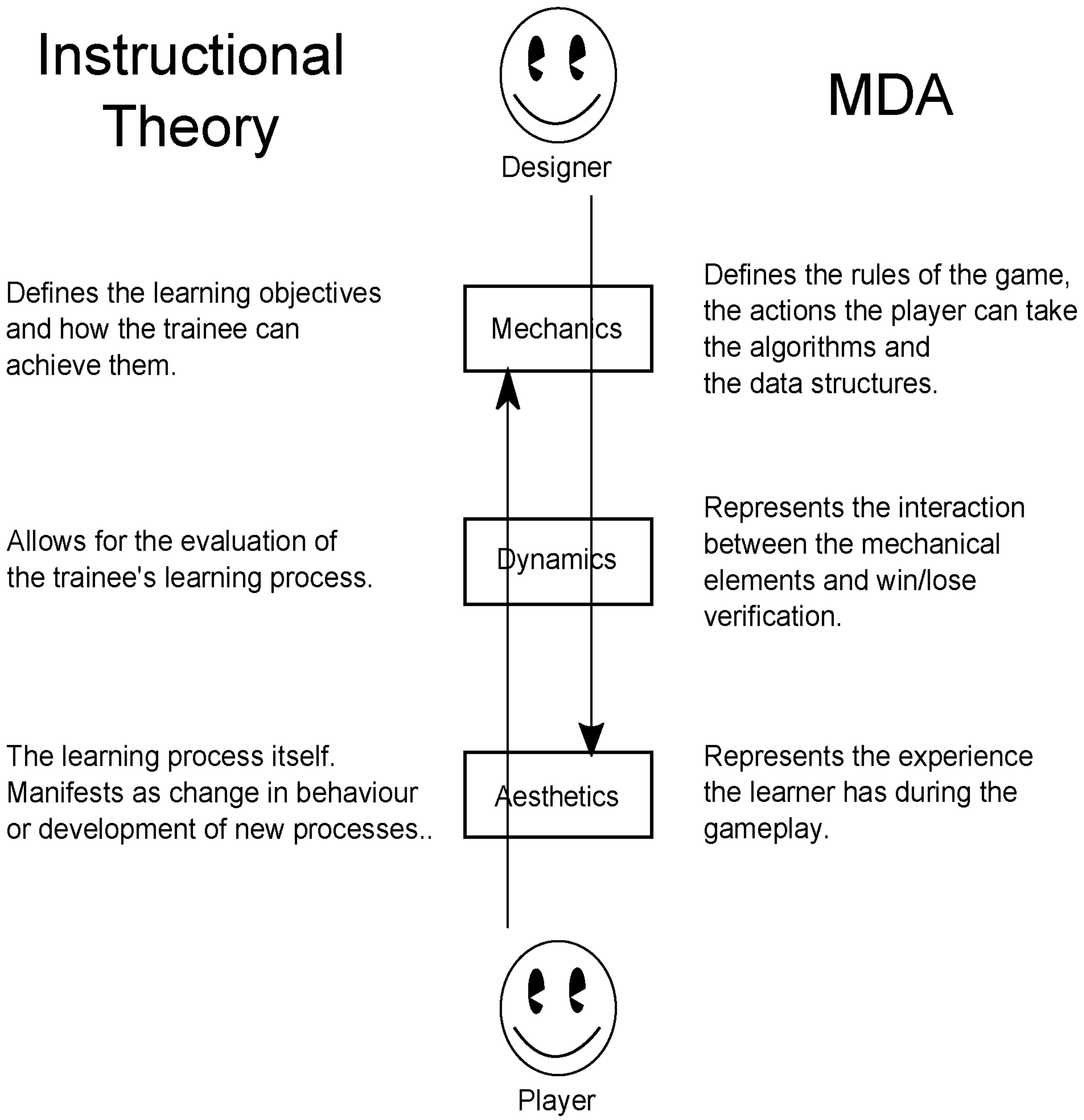

FIGURE 34 – MDA model, with the interaction between Game Designer and Player through the game elements. Source: (HUNICKE; LEBLANC; ZUBEK, 2004)

as the gameplay experience. The co-occurrence of experiences evidences that the instructional process happens in the Aesthetics layer of the MDA framework.

8 CONCLUSION

Live line maintenance is, intrinsically, a complex and hazardous activity. The work itself is, by nature and definition, exhausting and unsafe as the activity must be performed by professionals exposed to high electrical voltage, even when all the numerous safety equipment and procedures are observed.

The environment to which the electricians are exposed is intrinsically hazardous, as they are in a constant basis exposed to high electrical tension and electromagnetic fields. Both of these elements can be fatal under particular conditions, either by producing electrical discharges by touching an electrical conductor or due to a possible electromagnetic discharge to a grounded element.

To protect themselves from these hazards, the workers must wear heavy protective gear that can in itself create difficulties, such as movement restriction and thermal discomfort. While the previous causes an inconvenience, the latter can have more serious consequences, such as dehydration, excessive fatigue or even hyperthermia. These elements are so vividly present in the working conditions that they frequently report those and ask for replacement during the activities, as these conditions prevent them from putting the necessary effort in the maintenance activities or they find their hands shaking.

As the environment is typically unfriendly, the training process must be done as carefully as possible to avoid injury to trainees that get exposed to situations above their skills. Currently, the training is done in the form of theoretical classes in order to certify that the professionals are ready to go to the field and, once in the field activity, the training assumes a progressive responsibility model, during which the trainees get to the field with fewer responsibilities and pick more up until they graduate and are considered fully trained field personnel.

For the training process to become more effective, the trainees should come into the field with some practical knowledge in the activity to be performed, having already familiarized themselves with the tasks to be performed during the maintenance. However, in such a hazardous environment, as inexperienced technicians may represent harm to themselves or others.

In this context, the practical activities should be included in the training activities in a safe manner, in which the trainees can make mistakes and experiment freely. This is not possible in the current training scenario, in which the classes are mostly theoretical.

To allow for the safe inclusion of these activities in the process, virtual reality presents itself as a viable option. This kind of virtual learning environment can be used to familiarize the trainees with tool usage and how to navigate the environment properly, as the trainees can be transported into a safe proxy to the real environment, in which they can train the sequence of activities to be performed in reality.

The RV2 project was created to meet this necessity and to research manners through which the trainees can interact with a virtual environment to perform much of the same activities as they would in the real world. The project does not aim to reproduce the real world in terms of tool manipulation, but to allow for the trainees to familiarize themselves with the activities that should be performed and to memorize the task list through which they must go during the maintenance procedure as a manner to improve training and safety conditions.

For the system to complement properly the training process, it needs to have a theoretical background that supports both the gamification and the instructional components of the process. In order to address this requirement, Gagné's pedagogical model and the MDA framework were used to show how the system could enhance the training procedure, creating a theoretical backbone to this process in particular and to a unified analysis for gamified training systems in general.

Initially, to perform the implementation of the training environment, it was necessary to harvest information from the instructors and to codify it in the virtual environment. To allow such a task, the instructors had to share their knowledge with the developers in order to allow them to present an environment as faithful as possible to the trainees. However, such interview proved itself to be especially difficult to be conducted, as the developers did not have the necessary knowledge to ask the questions to the instructors and the instructors did not know exactly in which points the developers were interested.

To solve this problem, this work presents an interview method that makes the specialist knowledge available to the developers and allows them to quickly familiarize themselves with the context in which the professionals operate. By applying a gamification component to the interview, it was possible to let the instructors to exteriorize their knowledge and for the developers to create the rules of the virtual environment based on the needs of the instructors and of the instructional activity.

As the system was developed, the outcome had to be evaluated for the instructional effectiveness and if the trainees accepted the virtual learning system as a learning tool for their continued formation. Hence, the need to create a method for gathering the opinion of the trainees regarding the functionalities available in the virtual learning environment presented itself.

Furthermore, the trainee experience had to be evaluated to assess if the trainees felt motivated to use the virtual learning environment regularly. This factor must be verified as the motivation to interact with the system is a key factor to the incorporation of the system in the training habits.

The MDA framework was chosen to fully understand the components of the virtual learning environment, as it is a well defined framework and has broad application in the Game Design discipline. This framework, however, does not relate to any learning theory, as it only has the purpose of analysing games as entertainment and it needs to connect to the Gagné's Instructional Theory, chosen as the base by the project team.

For evaluating how the trainees experienced the system, it was necessary to gather their subjective input to assert how the trainees interacted with the system and how they felt about the virtual learning process. To fully appreciate the answers provided by the trainees, a subjective interview process was devised. The challenge at this point is how to process these answers in a manner in which the meaning that the trainee intended gets correctly translated into analysable data.

To allow for the process of the meaning of the interviewees' answers, the Thematic Analysis technique was applied to put in evidence the subject intended by the interviewee. In this analysis, the interview transcripts were scanned and the themes were marked and accounted, showing what the main concern of the trainees is during the training process.

By interpreting the themes and grouping them in the same categories, the analysis focused in two techniques, initially the interviews were scanned for predefined themes, in which a preset framework was defined and the interviews were scanned for which excerpt fit in which theme and in a second scan, the interviews were scanned for organic themes, which account for the ones that the trainees themselves expressed in their talk.

The predefined themes were set to be the dimensions of the UX framework defined in (ISO, 2018), with special attention to the efficiency dimension, that corresponds to how useful the interviewee feels that the system meets their needs. During this analysis, it was verified that the interviewees mostly felt that the system is efficient and innovative.

During the organic themes analysis, the interviewees could express what the expected outcomes from the system interaction were. In other words, at this point the interviewees could express what they expected from the learning environment. In this step, the interviewees expressed that they felt that the work environment is unsafe and also the need to memorize the maintenance steps.

In a complementary manner, while searching for the organic themes, it was possible to verify that the interviewees felt that the virtual learning system could help them to improve the needs detected as organic themes. This verification comes as further detail of the efficiency dimension in the UX theory.

Regarding the adherence of the system with the frameworks chosen for the instructional aspects and the game design aspects of the process. In the MDA framework, the Mechanics layer corresponds to the rules of the game. In the case of this virtual learning environment, as the activity steps were embedded in the development process, the instructional design corresponds to the Mechanics layer of the MDA design.

Furthermore, the trainee experience was collected using the interview process, as it was the manner available to assert how the trainees feel about the system. In this case, then, how the trainees feel corresponds to the processes that occur in the player in a game, or a serious game in this case, which corresponds to the Aesthetics element of the MDA framework.

Hence, this correspondence between the MDA framework and the Gagné's Instructional model can be created to enhance the methodology for creating serious games in a more structured manner. By thinking on the Mechanics element as the Instructional Design process and the Aesthetics element as the transformations and learning that take place in the trainee, both models can be fused in a functional model to create learning systems.

From the interviews, it is possible to conclude that the learners feel that the system is effective and can help them to achieve their safety and learning objectives. These elements should be prioritized in the future development of the system, in which new features can be added to enhance the functioning of the virtual learning system.

Another interesting data from the interviews is that the field maintenance personnel said, unanimously, that they would like to interact more with the system. This answer shows that the target audience feels that the system is valuable and that it can help the training process. Moreover, this answer can be interpreted together with the data from the interviews and verify that the UX theory states that systems with high efficiency get used more frequently. As the interviews showed that the trainees feel the system could help in the aspects they most desired, namely safety and the memorization of steps, this results, then, in a high efficiency score.

This work shows that the maintenance activity is widely seen as high risk and that the created system is highly regarded by the intended audience. The data shows as well that the field maintenance personnel feel the training process can be enhanced by the application of the virtual learning system, fact shown by the occurrence of high scores for the efficiency metric, reflecting that the interviewees stated both that they felt the working environment is unsafe and that the virtual system helps improving the task security and the need to memorize the maintenance steps.

By creating a correspondence between the MDA framework and the Gangé's Instructional process, the developed serious game gets the needed theoretical support.

The presented technique reinforces the established theory that states that an efficient and stimulating serious game captures, indeed, the attention of the players and encourages them to keep playing, which, in this case, translates into further professional training.

The framework presented in this work allows, then, to analyze a serious game in the light of both the instructional game design techniques by creating a correspondence between Gagné's instructional theories and the Mechanics, Dynamics, Aesthetics framework in a manner that is relevant to both trainees and instructors. This conclusion confirms the original hypothesis and enables the creation of a unified framework in which virtual environments can be analyzed.

8.1 RESEARCH LIMITATIONS

This work was limited mostly by the COVID-19 pandemic, which prevented the application of usability tests and the sharing of the HMD among pupils. The great risk was of contamination due to proximity of the device and the user's nose, mouth and eyes, exposing the users to contamination from fluids in these areas.

Another time related factor that limited the scope of this work was the long time needed to acquire the equipments which would allow for the research team to test the virtual environment in parallel with the development team. This delay prevented premature testing and forced the teams to share equipments across different geographic locations.

Another time related factor was that the process for the definition of the activity to be modeled took longer than anticipated. This enabled a scientific contribution on the interview process for the creation of the instructional activity, but prevented the implementation to begin earlier.

All these time related issues contributed to shorten the amount of data available for conclusions to be drawn. Furthermore, it would allow more time for the trainees to familiarize themselves with the system, allowing the audience to be more proficient on the system and more feedback to be taken in consideration during the development process.

8.2 FUTURE WORKS

Initially, more interviews need to be done to better assert how the trainees experience the system and how their skill evolution influences their answers. This will allow for more data to be collected and fed to the development activity.

Other training scenarios should be included in the system, as a means of diversifying the training activities and accomplishing other training goals. This will diversify the training portfolio and allow for the generation of further data concerning trainee interaction.

As a means to diversify the training environment, further development should be performed in the relationship between object and their behavior, as to create non deterministic relationships between them and allow for numerous tools to produce the same effect. For instance, a nail should require a tool that can push, either it be a hammer or a maul. In this sense, the tools should be represented by their behavior, not their identity.

Future works should also include treat the possibility of using Augmented Reality in the development of training scenarios. This would allow for the application of new interaction forms, as well as reduce ocular fatigue.

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APPENDIX 1 – SEMISTRUCTURED UX QUESTIONNAIRES

1.1 INITIAL VERSION

This initial version of the questionnaire was used in the first training event followed by an interview. It was created as a means of asserting wether the interviewee had experience with live line maintenance or not and, in the case of a positive answer, how much experience.

In this version, one of the guidelines was to stablish if the interviewees had practical experience and if it was possible to them to verify how similar the virtual environment would be from the real environment. This similarity was initially considered a strong point to the the virtual environment, but it lost relevance as the focus shifted to the User Experience theory. This was the point of question number 2, which got supressed in the final version of the document.

Question 3 tried to analyse how the users felt regarding the system Perspicuity, which defines if the system allows the users to perform the tasks they desire in a way that makes sense to them. This is a measure of how easily the users can convey their desires to the system and have their wishes understood by the system.

The next question, question 4, was designed to assert how useful the trainee felt the system would be. This question put in evidence the scores of Efficiency and Dependability the user feel towards the system.

Finally, qestion 5 was used to define how the user feels towards the Atractiveness of the system. This a valence dimension that defines how much the users liked the system.

All the questions in this questionnaire were developed as an initial framework to allow for the assertion of how good the user experience is in the opinion of the user. It is necessary to reassure that these questions are instrinsically subjective to the user, instead of having an objective characteristic.

1. In which area of the company do you work?

2. Comparing the experience you had in the virtual environment and the experience you had in the real environment, how would you describe the similarities and the differences?

3. Was there anything that you wanted to do and the system did not allow you to do? What prevented you?

4. Which are the main benefits that you perceived in the system deployment? As part of the training routines? Is there any benefits?

5. In your opinion, is the system attractive? What would make you spend more time in it?

1.2 FINAL VERSION

1. Are you from the live line maintenance team?

2. How long do you work with live line maintenance?

3. Did you ever performed a maintenance activity similar to the one in the virtual environment?

4. How would you compare the virtual environment with the real environment?

5. What do you think is the best part of the virtual experience?

6. What do you think is the best part of the real environment over the virtual environment?

7. Was there anything that you wanted to do in the virtual environment and you could not?

8. Do you think the virtual environment can improve the training process?

9. Did you like to use the system? What would make you spend more time in it?

10. Did you like the system?