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Cities as serious games.
How game applications can contribute to sustainable urban development

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

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To the loves of my life, Mum, Dad, Andrea and Claudio

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Summary

This thesis explores the role of serious games as learning tools for promoting knowledge on sustainability issues in educational contexts, such as universities. Hence, they contribute to the promotion and awareness of virtuous behaviours aiming at Education for Sustainable Development (ESD). Serious games are real games with the purpose to impart knowledge by playing. Above all, they are designed for a primary purpose other than pure entertainment and are consequently also defined as learning tools. For that reason, the aspect of learning assumes an interesting role in studying the extent to which serious games are actually able to teach. In particular, this task may be performed in two ways: through "learning by playing" or "learning by making". This thesis will analyse both cases through the proposal of an analytical flow chart based on game mechanics and Sustainable Development Goals (SDGs).

The main research questions behind this work are: how do serious games act as learning tools to convey sustainability concepts? And more specifically, how do serious games promote areas of knowledge and practice that relate to and encourage sustainable urban choices and behaviors?

As my literature review shows, the use of serious games has recently grown. However, this growth is mostly limited to contexts of health care, military, mathematics, political, religious, while it has been of little relevance for engaging people in regards of sustainable development issues. Starting from the analysis of the literature, I made a new classification of existing serious games with the aim of identifying which and how SDGs were being addressed. The outcomes proved that there are some connections among actions, challenges, dynamics, game scenarios, and sustainable goals. Subsequently, in an effort to analyse these connections, according to exploratory sequential mixed methods, I have defined an instrument that can be tested with sustainable serious games. Therefore, I propose an analytical flow chart. Firstly, according to "learning by playing", this flow chart will be tested on existing serious games and secondly on other games that will be created specifically to

deal with the SDGs based on “learning by making”. Because of this, specific serious games for sustainable educational purposes have been created through a university competition: Talenti Polito Challenge. This experience is the main fieldwork of this thesis, and it has been conducted completely online during the Covid-19 pandemic. Talenti Polito Challenge, which took place in Politecnico di Torino, involved the participation of 59 students with different backgrounds and skills. Their aim was to design appropriate serious games to envision a more sustainable university campus. This was achieved by creating a series of products that, through game mechanics, were able to raise awareness of sustainable development. Moreover, the serious games were developed to explore the interaction among relevant SDGs by involving specific targets of sustainability: Transport and sustainable mobility; Renewable resources and energy production; Waste; Building and energy efficiency; Food; Water. Students conceived eight serious games, seven of which are multiplayer board games, and one is a digital single-player game (app). Such games, at the end of the challenge, were assessed according to the project’s initial brief by the tutors and professors involved.

The winning serious games were examined from two perspectives: the first concerning educational aims given by the Challenge experience and the second regarding the results of the application of the analytical flow chart.

According to the first objective, other than learning by playing, the students also learnt through game-making. This singular opportunity actively engages teachers and students in a meaningful learning process. Through the creation of a post-experience questionnaire submitted to the same 59 students, it was possible to assess the challenge as a novel approach in ESD methodologies. The outcomes of the questionnaire showed that students positively assessed the effects of “learning by making”, the teamwork abilities encouraged by the activity and the likelihood of repeating a similar experience. Moreover, students' self-evaluation on the three macro-dimensions of sustainability (i.e., economic, social, and environmental) increased at the end of the challenge compared to the initial phase.

Secondly, from an experimental point of view, the application of the analytical flow chart shows that the game mechanics are quite close to the practices required by the SDGs, considering both benefits and limitations.

The overall results obtained by the twofold assessments of this challenge show that this learning approach can be positively repeated in other educational frames and can indeed be considered an innovative approach in ESD methodologies.

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List of abbreviations

ASVIS: Alleanza Italiana per lo Sviluppo Sostenibile

CDS: Citizen design science

ESD: Education for sustainable development

EU: European Union

GBL: Game-based learning

GDD: Game design document

ICT: Information and Communications Technology

IoT: Internet of things

IT: Information technology

MDG: Millennium Development Goals

MEEGA: Method for Evaluating of Educational Games

MEEGA +: Evaluation of Method for Evaluating of Educational Games

POLITO: Politecnico di Torino

SC: Smart cities

SDG: Sustainable Development Goal

SDG11: Sustainable development goal number 11

SD: Sustainable Development

SG: Serious game

SSG: Sustainability Serious game

SSI: Sustainable Society Index

UN: United Nations

UX: User Experience

WCED: World Commission on Environment and Development

Outline of the chapters

This thesis is structured in 7 main chapters.

Chapter 1 starts with the introduction of the thesis, with an overview of the main topics investigated to conduct this research. These topics concern Education for Sustainable Development- ESD, SDGs and serious games. They are investigated according to the definition of the research questions. Furthermore, this chapter explained the methodology framework adopted to carry out the research in all its phases. The exploratory mixed methods proved to be the most suitable for this type of work, proposing the analytical flow chart, an exploratory instrument to be tested in serious games.

Chapter 2 is entirely dedicated to the Gamification world and serious games. The analysis of the literature opens the chapter with the definition and characteristics of gamification. The analysis pursues on serious games, exploring related characteristics, applications, strengths and weaknesses. Particular attention is focused on the assessment of learning in serious games to analyse two possible situations: "learning by playing" and "learning by doing".

Chapter 3 concerns smart cities and sustainable development. These two concepts are linked by the need to provide information and disseminate knowledge among people (smart people for smart cities) in regards of urban sustainability issues. Furthermore, special consideration is given to SDGs and SDG11-Sustainable cities and communities. In particular, linkages among the goals are studied in detail through "Interlinkages visualization tool" developed by JRC and subsequently used in the analytical flow chart.

Chapter 4 relates to educational studies and ESD. The analyses conducted in the area of ESD allowed to discover questionnaires and surveys used in this context. Further in the text, the analysis pursues through a new classification of 67 games, according to their topic, year, target and SDGs addressed. This new classification determined the design of the analytical flow for exploring SDGs and interlinkages in games.

Chapter 5 is principally dedicated to the description and the outcomes of the Talenti Polito Challenge. 59 students designed and developed 8 new serious games for a more sustainable university campus. Two suitable questionnaires were established

and submitted to assess firstly the developed games and secondly, the challenge experience as a novel approach for ESD and for “learning by making”.

Chapter 6 is exclusively dedicated to the applications of the analytical flow chart. 6 serious games were identified for this study, 3 from the new classification (Energy City, Urban Climate Architect, New Shore: a game for democracy) and 3 others from the challenge experience (Patent, Polinks and iPolito). The objects of this study are the game elements, which will be explored both from the point of view of the game mechanics and from that of the SDGs. Moreover, two macro steps define the phases of the flow chart analysis: the first one is meant to identify SDGs and targets, while the second one aims at investigating possible interlinkages with other goals.

Chapter 7 is finally dedicated to conclusions, limitations and further developments. Within this last section of the thesis, the research questions set out in Chapter 1, and explored in the course of the chapters, are taken up to conclude all the research described in these pages. Lastly, some possible future applications and uses of serious games are proposed.

Chapter 1

Introduction

Chapter One is mainly dedicated to the bibliographic overview of the main topics of this thesis and the identification of the research gaps. Firstly, it will lay out the analysis of the literature background on sustainable development and look at how to spread knowledge on sustainability issues. An initial overview of the literature shows that new educational tools are being used recently, including serious games. For this reason, the second section of this chapter focuses on defying the research questions that this thesis aims to answer. In fact, these have been defined with the aim of framing the role of serious games as educational tools for the promotion of sustainable practices.

The third section of this chapter examines the theoretical dimensions of the framework by describing and setting out the methodology of the research employed. More specifically, the overall methodological framework of this thesis is based on Creswell's research methods (2014). Among the theoretical worldviews defined by Creswell (2014), the pragmatic view is the one that best relates to the work phases of this thesis. This view is in fact characterised more by consequences of actions, problem-centered attention and real-world practice oriented. In this thesis, problem-centered is focus on education for sustainable development.

Through a consequence of actions, including a new classification of sustainability games, the application of a new analytical flow chart and a university challenge, it

will be possible to test reality-oriented practices. Such practices focus on serious games' applications mentioned in this chapter and discussed in greater detail in Chapters 4 and 5.
Finally, the conclusion of this chapter reports the final framework of the thesis: a pragmatic philosophical worldview characterized by "exploratory sequential mixed methods".
According to pragmatical worldview, this study first begins with a qualitative research phase presented through a literature review and it explores the use of serious games for educational purposes. The information gathered was then used to question how many and which games were available to provide education for sustainability. This first qualitative phase helped construct an instrument to use in the follow-up quantitative phase: the analytical flow chart.
The second quantitative phase is characterised by Talenti Polito Challenge, in which the analytical flow chart is specifically tested, evaluating both its benefits and limitations.

1.1 Background and research gaps

Today many cities are facing urban and social challenges in terms of sustainability. Such challenges are related to territorial conflicts, poverty, gender equality, climate action, clean energy, and responsible consumption and production (George et al.,2013; Pradhan et al., 2017). In this perspective, an emerging and pivotal concept is that of "smart cities and communities". Although an official definition of smart cities is still missing, these cities convey different aspects that can be analysed from various sustainable points of view regarding social, economic and environmental matters. This intersection between different and sometimes conflicting disciplinary areas makes the proper understanding, development and management of smart cities an extremely challenging task (Albino, Berardi, and Dangelico 2015; Dewalska–Opitek 2014). For this reason, the 2030 Agenda for Sustainable Development provides strategic guidelines to support the future development of cities and communities, identifying 17 Sustainable Development Goals (SDGs): an urgent call for action for developed and underdeveloped countries in a global partnership (sustainabledevelopment.un.org).
Notably, SDG 11 - Make cities and human settlements inclusive, safe, resilient and sustainable – aims to achieve urban growth and safety development in many cities across the globe. Among the different aspects highlighted by SDG11, citizens' involvement and creation of sustainable communities plays a vital role.
It is always imperative to bear in mind that every decision and action taken in regards of projects in cities has an impact on the citizens' quality of life. More specifically, by allowing people to participate in urban projects and initiatives,

making them active stakeholders in urban activities or analyses, the achievement of specific goals for urban development could improve. According to Mueller et al. (2018), Citizen Design Science (CDS) is an essential approach to involve citizens in urban transformations from a sustainable perspective. CDS concerns citizens' involvement in planning and management process in cities, through an easily accessible design. Inherently, it is based on three fundamental pillars: Citizen Science, which refers to the participatory aspects and data collection; Citizen Design, which allows citizens to actively design; and finally Design Science, essential for transforming the citizens' design proposals and ideas into tangible urban drawings and plans (Mueller et al. 2018). As a result, CDS provides different proposals of participation and people involvement. Usually, CDS consists of questionnaires, focus groups, roundtables, workshops, conferences and meetings. However, according to the literature (Leydesdorff and Deakin 2011; Nalbandian et al. 2013; Joshi et al. 2016), the need for new participatory methods emerges. Amongst the tools identified within the CDS approaches, gamification appears as one of the most suitable for this purpose. Although in the literature gamification is connoted in several ways, the most common definition is expressed by Deterding et al. (2011): "the use of game design elements in non-game contexts". Through gamification applications, it is possible to build various challenges to test people's skills: the main purpose of gamification is to improve people's knowledge on given topics (Maestri, Polsinelli, and Sassoon 2015).

The gaming approach combined with the use of new technologies can allow people to express their ideas and opinions in an unexpected way, enhancing the motivational level (Mueller et al. 2018). In the broad context of games and gamification applications, serious games are learning tools which simultaneously offer entertainment and engagement, increase knowledge, raise awareness and tackle authentic issues (Emblen-perry, 2018). In a few words, Serious games are learning tools able to spread knowledge whilst entertaining.

Clark C. Abt referred to serious games for the first time in 1987, as he described them as games "that can be played seriously or casually by people. 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 not be, entertaining". In Clark's statement, the adjective "serious" refers to the learning aspect, concerning matters of great interest and relevance (e.g., energy transition, sustainability, economic growth, climate action), correspondingly raising intricate and challenging issues, which may potentially trigger severe consequences. Although many years have passed since Abt's definition, serious games are still used for the same purpose. Originally employed for military purposes, they were later followed by political aims, health and educational fields. In the last 10 years,

they have also been applied to tackle real issues related to climate change, affordable consumption and production, use of natural resources, urban planning and sustainability (Ouariachi, Olvera-Lobo, and Gutiérrez-Pérez 2018; Neset et al., 2020). Serious gaming for climate adaptation—assessing the potential and challenges of a digital serious game for urban climate adaptation. Sustainability, 12(5), 1789. Moreover, serious games are characterized by multiple learning aims, which can be applied in many areas and target all age groups (Mouaheb et al. 2012). According to the literature, since serious games are defined as learning tools, considerable attention has recently been drawn to the importance of learning evaluation (Von Wangenheim and Shull, 2009; Kirkpatrick and Kirkpatrick 2006; Gentile 2011; Ouariachi, Elving, and Pierie 2018; Ouariachi, Olvera-Lobo, and Gutiérrez-Pérez 2018; Petri and Von Wangenheim 2016).

The difficulty of measuring the effectiveness of learning is widely recognized within the education community, since the majority of the studies do not adopt evaluation practices from this community nor discuss threats to their validity (Petri and Von Wangenheim 2016). What arises from the literature is that there is a lack of a valid and replicable method for measuring the level of learning in educational game. Most evaluation methods, however, refer to the studies of Bateson (1972), who classified the learning assessment phases into 3 main moments: IN (when the game begins), THROUGH (during the game sessions) and BEYOND (when the game has ended). The efficiency of learning transmission can be assessed on different levels following Kirkpatrick's Four Levels of Evaluation (Kirkpatrick and Kirkpatrick 2006), a popular and common model. Such model is used for the evaluation of training programs and the learning effects of serious games. These 4 levels are reaction, learning, behaviour and results. According to Petri and Von Wangenheim (2016), there are mainly 7 approaches that use Kirkpatrick's levels of evaluation: three frameworks, two scales, one method and one model. Among these approaches, particular attention is given to the Model for the Evaluation of Educational Games (MEEGA) developed by Savi et al. (2011) to assess the learning level within educational/serious games.

MEEGA is a model focused on evaluation level 1 of reaction (Kirkpatrick and Kirkpatrick 2006) that captures student’s reactions through a standardized questionnaire, after they have played games. Moreover, MEEGA measures 3 dimensions: motivation, user experience and learning according to the ARCS model (Attention, Relevance, Competence, Satisfaction) and it has been developed by using Goal, Questions, Metrics- GQM (Basili, Caldiera, and Rombach 1994) to explicitly define a measurement program. Since MEEGA is a standardised model and tends to be replicable, it was used as a reference model for the creation of the first questionnaire submitted to professors and tutors of the Talenti Polito Challenge. The first questionnaire was formulated to define the winning games of

the challenge. This was structured in 16 questions scored with a 5-point Likert scale defined according to the initial requirements of the challenge which concerned, among other things, game mechanics, a business plan and knowledge of the SDGs. In this regard, in fact, the changes and adjustments to this questionnaire focused particularly on learning about sustainability issues. In this case, the level of learning was based on the experience gained through the matches played. This form of education is known as “learning by playing”.

In parallel, the challenge experience was also an educational opportunity for the students. This is known in the literature as “learning by making”. In this way, the students involved, learned and acquired knowledge about sustainability in this case, through the actual creation of the games.

Subsequently, a second specific questionnaire has been developed for evaluating the entire experience of the challenge, mainly considering two factors. The first one regards the challenge as a chance for designing and especially prototyping a new tool, interviewing students on aspects that have been successful or unsuccessful during the challenge. The latter analyses show the outcomes in terms of “learning by making”, effectively assessing how formative it was to create educational serious games.

Through the analysis of the literature, it was also possible to study the classifications made regarding available sustainable games. These in fact, including my new classification (Cravero, 2020) show that there is a significant number of 'sustainable games' available and playable on the market today. Most of the classifications, databases and online platforms that contain this type of games usually classify serious games through well-defined categories. Among those consulted for the study of this thesis, such as Serious Games Classification or Games for Sustainability, one can easily distinguish the labels that are assigned to games, such as genre, type, target audience, cost, duration, number of players, plot and many others. With regard to sustainability, the most commonly used labels are game theme such as green urban management, urban and sustainable planning or environmental issues, game topic such as sustainable urban development, sustainable actions for the environment plus how many and which SDGs have been addressed.

However, what seems to be missing is a label identifying the 'serious' aspect of these games. The classifications do not reveal sensitive data on how these games impart knowledge to players. There is a certain degree of uncertainty about how sustainability concepts are perceived and assimilated by players. This lack of information may be explained by the fact that there is a tendency to focus on a final and overall assessment of the effectiveness of the game itself. As a consequence, there is still a lack of research on how sustainability lessons can be learned from the actions, game strategies or choices made by players. In this regard, it is possible to

find an answer in game mechanics, formally defined by Werbach and Hunter (2012), who classified them in 10 groups. Game mechanics are the rules that regulate and guide the player's actions and the game's response to them. The mechanics of a game effectively specify how the game will work for those who play it. Another definition was provided by Lundgren and Björk (2003) who explain game mechanics as "any part of the rule system of a game that covers one, and only one, possible kind of interaction that takes place during the game, be it general or specific (…) mechanics are regarded as a way to summarize game rules".

In an attempt to answer these questions, I propose an analytical flowchart into the analysis of game mechanics. The proposal has a twofold objective: the first concerns the identification of game mechanics to one or more sustainable objectives. The second is to identify synergies or trade-offs between the various sustainable actions carried out within the game. *Figure **1*** summarises the main stages of work which will be dealt with in the chapters of this thesis.

To conclude, this thesis has multiple aims. The first one is to understand how serious games can be utilised to spread knowledge on sustainability issues, in particular SDGs and sustainable development. The latter concerns the efficiency of a challenge experience as a novel approach for ESD through “learning by making”.

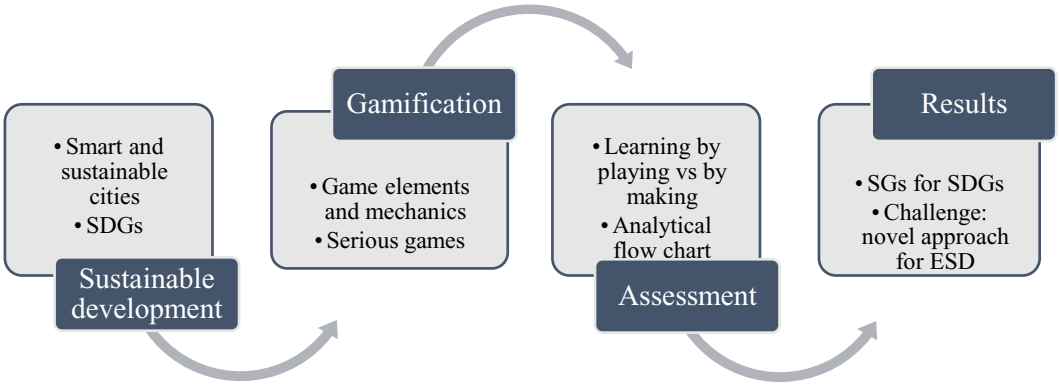

Figure 1_ Main steps of the research process of the thesis

1.2 Objectives and research questions

After having previously described the areas of research and highlighted the gaps, in this paragraph I will define the research questions that this work aims to answer. As mentioned above, the main topic of this thesis deals with education for sustainable development using serious games. This use has rapidly grown in the context of instructive tools, both traditional and innovative, mostly as they allow to tackle real and challenging situations by reducing their complexity (De Heer et al. 2010). Probably their wide dissemination is because serious games are extremely valuable as they offer many advantages. Most importantly, they support effective decision processes as they acquire data from people through a very simple method. Such kind of games lends itself to various uses and can be applied in a variety of contexts. Since their first application in military context in 1948 (Wilkinson 2016), serious games have been implemented in different disciplines for encouraging learning and improving teaching methods. They are a suitable tool to transfer knowledge, manage different research and to solve practical issues (Gee, 2003; Gentile, 2011). Although serious games are quite widely used in contexts including smart cities and urban development, they are rarely employed in regards of sustainability matters, such us "Energy transition game", "Cities: Skylines" or "The world's future". Since the very beginning, my research approach initiated from literature research on the use and application of serious games with the aim of spreading sustainability knowledge. From this, I have formulated the main research questions of this thesis:

How do serious games act as learning tools to convey sustainability concepts? And more specifically*, how do serious games promote areas of knowledge and practice that relate to and encourage sustainable urban choices and behaviours?*

In order to understand how to proceed with the research, I have outlined more specific questions that will help me further define the context of the research, the catchment area of the games and the realistic ways of transmitting knowledge to the players.

The research started with an analysis of the bibliographic literature by consulting 7 of the most used databases in the scientific community: Google Scholar, Scopus, ResearchGate, SpringerLink, Web of Science, Sage Journal and Google books. To further analyses such databases, a study was made, taking into account data published from 2007 to 2018 which included the following keywords: "digital

game-based learning", "educational games", "environmental games", "game-based learning" and "serious games".
Given the topic of the study, other types of databases were also consulted. These relate to online platforms that contain both sustainable playable games and classifications based on the characteristics that distinguish them. Such databases are Serious Games Classification, Games for Change and Games4sustainability.
Consultation of these online databases has proved useful in giving a picture of the current situation of serious sustainable games developed. In these databases, various information on sustainable games is collected and schematised. By accessing and reviewing this information, it is possible to study the connections between game mechanics and the sustainability content that should be conveyed to the players.
In this context, the applications of this type of games are investigated with the aim of finding connections with the learning component and not just the play component. In recent years, the importance of sustainable development has increased. Moreover, due to the introduction of SDGs in 2015, new games have been created with these goals in view. In this respect, a number of companies, societies and research centers have developed serious games that are roughly in line with SDGs.

a) How can serious games be used with students to spread knowledge on sustainability issues?

This thesis is focused on sustainability themes, paying particular attention to sustainable development and SDGs. The concept of sustainable development is currently one of the goals of the world's policy agenda. For this purpose, in 2015, the 2030 Agenda defined a list of 17 SDGs (Sustainable Development Goals), that are the blueprint to achieve a better and more sustainable future for the next generation (sustainabledevelopment.un.org). The SDGs have been defined according to the triple-bottom-line sustainability approach, by including elements of economic development, social inclusion and sustainable environmental management (Sachs, 2012; Klopp and Petretta, 2017).
Since many of the goals included in the SDGs are multidimensional and cover the three main dimensions of sustainability, many synergies, complementarities but also and trade-offs can exist among the goals.
Today, the Agenda is working to provide strategic directions to support the future development of cities and communities, by encouraging and supporting people's involvement towards sustainability concerns. For such reason, it has become important to convey behavioural changes to prioritize the Education for Sustainable Development-ESD (Sauvé, 1996; Carteron, Haynes, and Murray, 2014).

In this context, serious games could play a critical role as a pedagogical tool of ESD, providing players opportunities to understand the complex issues of sustainability. The target group of players referred to in this thesis is students, and in particular university students. The latter will be the future professionals who will soon enter the world of work and will therefore have to face challenges in economic, social and environmental fields. In this connection, serious games have emerged as a powerful means of spreading knowledge also about sustainability issues. Through their use and game machines that distinguish them, players learn by playing (and making) and entertaining themselves. Hence, the first means of educating, is identified in "learning by playing" and secondly also in "learning by making".
These two fields of research are still being explored; researchers are currently working on the effects generated by learning by playing games and learning by making games (Garneli et al., 2013). This is an expanding area, and what emerges from the literature is that new studies and experiments are needed (Kafai and Burke 2015). At the moment there is relatively little data available on the effects of learning by playing or doing and more incentives are needed to strengthen the underlying theory. For this reason, it seemed relevant to ask the following question, to see how the effects of game applications in terms of learning could best be assessed.

b) *Which are the most successful methods or strategies which assess the effectiveness of learning by playing serious games?*

Serious games are defined in the literature as learning tools, conveying knowledge by also providing entertainment. Since they are education tools, a specific section of this thesis is dedicated to the evaluation of learning within serious games and in particular, to the transformative learning concepts. Although, it has emerged that assessments to estimate the efficiency of games in terms of learning are lacking in the literature. Hence, through this thesis I will define a means of evaluating the usefulness of games after they have been played and tested.
The difficulty of measuring learning effectiveness is widely recognised in the educational community, especially as most studies do not adopt standardised or replicable evaluation procedures.
Most numbers of studies use a simple research design in evaluation contexts (one-shot post-test only), where, usually, after the game has been played, subjective information is collected via non-standardized questionnaires or through informal interviews from the players (Von Wangenheim and Shull 2009).
Very few studies use a (quasi-) experimental design for evaluation (Pfahl, et al., 2004; Vogel et al., 2006; Von Wangenheim, Thiry, and Kochanski, 2009; Navarro & Hoek, 2009).

In terms of evaluation purpose, most studies represent explorative research focusing on learning effectiveness and enjoyability as well as the identification of strengths and weaknesses of the games.
A possible way to assess the knowledge transfer is to apply the research done on transformative learning which is subsequently described in Chapter 2.
As serious games are designed to influence the player's perspective, they aim to address serious and instructive learning methods.
When researchers ask what the motivations and learning benefits of serious games may be, it is necessary to investigate if and how serious games foster transformative learning (Mitgutsch 2011).
While most studies research the transmission of behaviour, knowledge, literacies and skills, little is known about deep and meaningful informative learning processes through playing serious games. Even though the potential of serious games for serious learning is promising, there is a lack of quantitative data. Hence, further qualitative research on players' experiences is required to determine if and how players change their self and worldview by playing serious games.

c) In the context of Education for Sustainable Development, can a challenge be a compelling and effective novel approach to be adopted for "learning by making"?

Otherwise, it is also possible to transform players into designers by asking them to create new games. The experience of the challenge is an interesting test to explore the approach of making serious games and learning by doing.
Through the implementation of serious games, the level of people's awareness of certain issues could be understood. People's awareness would increase by using games. The functioning of games as educational tools occurs precisely through the mechanics that compose and distinguish them from games used exclusively for leisure purposes. Elaborating the game mechanics by the players implies learning the structure of the system and thus the possible behaviours of the players themselves over time. This type of understanding is appropriate and provides effective learning. Therefore, serious games can represent a strategic pole to promote educational programmes and involve the adoption of a new lifestyle. Discussions, focus group interviews, questionnaires, and observations, can help to access this experience. These methods can be used as auxiliary tools to design or assess serious games. The action of "making tools", in this case making new serious games, can be the appropriate solution. Through the experience of "learning by making", people become creators, designers and developers. They can express themselves in different ways, actively create objects, mechanics, challenges, competitions, or collaboration in games, sharing their ideas and perspectives in a

new innovative way. The opportunity to design serious games to achieve specific objects can allow the designers to receive more or less immediate feedback. The experience of Talenti Polito Challenge can be a compelling chance to test the benefits and advantages of designing serious games for the specific aim of raising awareness on sustainability.

1.3 Research Framework

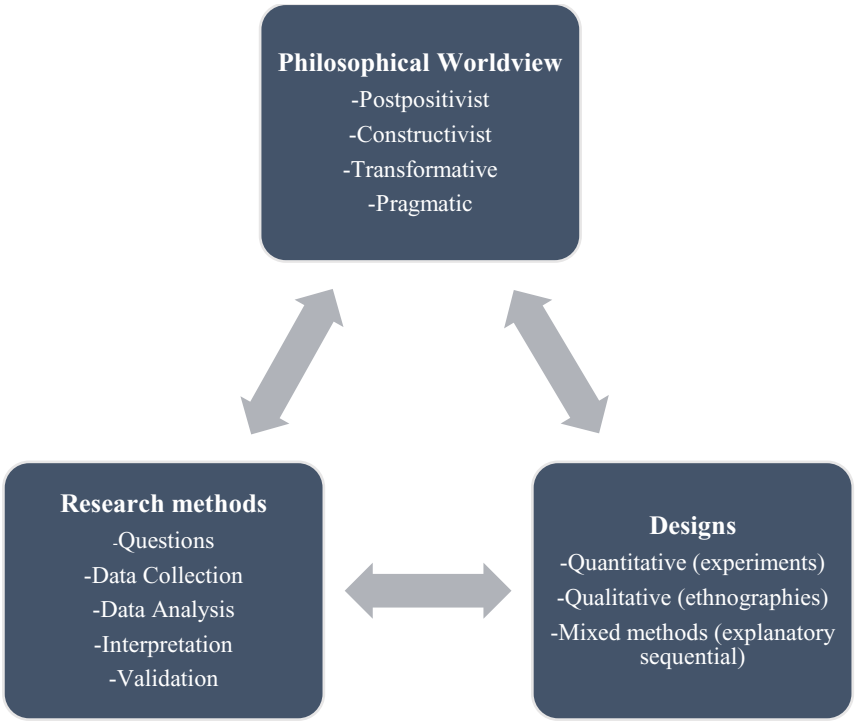

Figure 2_ Theoretical framework of a research (Creswell, 2014)

The research approach outlined in Creswell's studies helped me define the most important stages and processes of my research over the years, as described in this thesis. As the broad research approach is considered the plan proposal to conduct research, it involves the intersection of these three components: the philosophical worldview, the designs and the research methods (Creswell 2014) as shown in *Figure 2*.

The philosophical worldview is the assumption that the researcher brings to the study and even if the philosophical ideas remain subtly concealed (Slife and Williams 1995), they still influence the practice of the research and need to be identified. This information helps to explain which kind of research approach should be chosen whether it may be qualitative, quantitative, or mixed methods to carry out the study. For what concerns the worldview, a research idea or proposal might involve a section addressing the philosophical worldview proposed in the

study, a definition of the basic idea of such worldview and how this worldview has determined the approach of the research (Creswell 2014a). The term worldview indicates "a basic set of beliefs that guide action" (Guba, 1990, p.17). Worldviews arise based on discipline orientations, students' tutor inclinations and, if any, past research experiences. The types of beliefs held by individual researchers based on these factors will often lead to embracing a qualitative, quantitative, or mixed-methods approach in their research (Creswell 2014a). Currently, there is a discussion in the literature about what worldviews of beliefs researches bring to an inquiry. As shown in *Figure 3*, Creswell highlighted four worldviews that broadly debate post positivism, constructivism, transformative, and pragmatism. Generally, post positivism embodies the traditional form of research whereby the related assumptions are used more for quantitative rather than for qualitative research. Furthermore, this method comprises of empirical observations and subsequent measurements. In this view the main goal of the research is to verify one or more theory related the subject of study (Phillips and Burbules, 2000; Creswell, 2014a).
The constructivist view (also defined as 'social constructivism') is generally seen as an approach to qualitative research. Social constructivists base their views upon the assumption that individuals seek an understanding of the world in which they live. Individuals are believed to develop subjective meanings by directly experiencing certain objects or things. In this kind of worldview, the purpose of research is to rely as much as possible on the participant's views of the situation being studied (Crotty 1998, Creswell, 2014).
Conversely, other studies are founded upon the transformative worldview, a notion that arose during the 1980s and 1990s from individuals who believed that the postpositivist assumptions imposed structural laws and theories (Creswell, 2014). This worldview states that research inquiry needs to be intertwined with politics and a political change agenda to confront social oppression (Mertens, 2010).
In conclusion, the final worldview is pragmatism, defined by consequences of actions stating that generally, problem-centered research occurs through real-world oriented practice. This perspective is the closest to the methodology used to conduct this research and it is thoroughly described in the paragraph below.

Postpositivism	Constructivism	Transformative	Pragmatism
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation	• Political • Power and justice oriented • Collaborative • Change-oriented	• Consequences of actions • Problem-centered • Pluralistic • Real-world practice oriented

Figure 3_ Elements of the four worldviews (Creswell, 2014)

1.3.1 Pragmatic worldview

A pragmatic worldview differs from the previous as it arises out of actions, situations, and consequences rather than antecedent conditions. Attention is drawn to practical experiments, which through their application, provide solutions to the problems (Patton 1990). This concept was originally introduced in the works of Peirce, James, Mead and Dewewy (Cherryholmes et al. 1992) and other authors' such as Murphy (1990), (Patton 1990) and Rorty (1990). What is interesting about this approach, is that, instead of focusing on methods, the researchers emphasise on the research problem and apply all approaches available to understand it (Rossman and Wilson, 1985). Subsequently, other authors highlight that, in order to focus on the research problem in social science, mixed methods studies are employed. This way, the pluralistic approaches allow to derive useful knowledge regarding the problem. According to Cherryholmes (1992) and Morgan (2007), pragmatism provides a philosophical basis for research:

1. The mixed-methods used for this type of research draw freely from both quantitative and qualitative assumptions when they are used in the research.
2. The researchers have individual freedom of choice: they are free to choose the methods, techniques and procedures of research that best meet their needs and purposes.
3. The mixed-methods look at various different approaches to collect and analyse data rather than only complying to one single system (qualitative or quantitative).
4. To better understand the research problem, the work is based on a mixed approach providing both qualitative and quantitative data.
5. Pragmatists look at "what" the research is founded on and "how". Subsequently, they attempt to establish a purpose for their mixing methods and find reasons for which both qualitative and quantitative methods are needed.
6. The research always takes place in social, historical, political and other contexts.
7. Therefore, according to mixed-methods researchers, pragmatism opens the way to multiple methods, proposing new worldviews and different assumptions, as well as different forms of data collection and analysis.

In this digression the aim was to further understand which kinds of approaches would be most suitable for this thesis, appropriately investigating on sustainability issues through serious games. Since this work is not only based on quantitative methods as experiments (postpositivist worldview), neither does it rely on social and historical construction (constructivism worldview) or is it politics, power, or justice-oriented (transformative worldview), it can be analysed by means of the pragmatist worldview.
It is renowned how people's actions have led to devastating effects on urban, social, economic and especially environmental development. Thus, researchers across multiple disciplines are attempting to tackle the issue of sustainability, bringing it to the center of the contemporary debate. The concept of sustainable development is the focal subject of this work. In particular, through a mixed-methods research and a pluralistic approach, researchers are allowed to investigate the core problem, and consequently suggest real-world practice-oriented solutions, as supported in the pragmatism worldview.

1.3.2 Research Design

The research designs are defined as types of inquiry within qualitative, quantitative and mixed-methods approaches (*Table **1***), providing a specific direction for the procedures in the overall study. Particularly, they can be also be referred to as 'strategies of inquiry' (Denzin and Lincoln, 2011).

Table 1_ Alternative Research Designs (Creswell 2014)

Quantitative	Qualitative	Mixed methods
• Experimental designs • Nonexperimental designs, such as surveys	• Narrative research • Phenomenology • Grounded theory • Ethnographies • Case study	• Convergent • Explanatory sequential • Exploratory sequential • Transformative, embedded, or multiphase

Between the 19th and the 20th century quantitative designs were generally employed within psychology matters. Today, they are strategies of inquiry associated with postpositivist worldview. More specifically, this research method comprises of true experiments and less rigorous experiments, which are defined as 'quasi-experiments' (Campbell and Stanley, 1963). Furthermore, another experimental design is 'applied behavioural analysis' or 'single-subject experiments', whereby the experiment is administrated overtime by a single individual or a small number

of people. For example, a type of nonexperimental quantitative research is 'casual-comparative research', in which the investigator compares two or more groups based on a cause that has already occurred. In addition, design is defined as a nonexperimental form in which investigators use static correlations to describe and measure the degree of association between two or more variables or sets of scores (Creswell, 2014). Recently, quantitative strategies have consisted of complex experiments with many variables and treatments such as factorial designs and repeated measure designs. They have also involved elaborate structural equation models which incorporate causal paths and the identification of the collective strength of multiple variables. Among all of these quantitative approaches, the most popular are surveys and experiments. Surveys provide a quantitative or numeric description of trends, attitudes, opinions of a population through the study of a sample of such population. Cross-sectional and longitudinal studies are included through the use of questionnaires or structured interviews for data collection -with the intent of generalizing from a sample to a population (Creswell, 2014).

In contrast, experimental research tries to define if a specific treatment can influence an outcome. This type of research is evaluated by providing specific treatment to one group and withholding it from another, subsequently determining how both groups scored on an outcome.

Qualitative research designs are applicable in anthropology, sociology, the humanities and evaluations, and entail various types and complete procedures, for instance narrative research (Clandinin and Connelly, 2000), philosophical tenets and procedures of the phenomenological method (Moustakas, 1994), the procedures of grounded theory (Strauss and Corbin, 1990,1998; Charmaz, 2006; Corbin and Strauss 2008).

One of the most noteworthy designs of inquiry described above is narrative research, which arises from the humanities, and in which the researcher studies the lives of individuals, enquiring one or more individuals to provide stories about their lives (Riessman, 2008). Similarly, phenomenological research is a design of inquiry originating from philosophy and psychology, whereby the researcher interviews individuals gathering information on lived experiences of in regards of a phenomenon.

Another useful design of inquiry is ethnography, initially studied by Fetterman (2019) and Wolcott (2008) who summarized ethnographic procedures, and the various aspects and research strategies of ethnography, whilst Stake (1995) and Yin (2003) suggested processes involved in case study research. More precisely, in ethnography, which derives from anthropology and sociology, the researcher studies the shared patterns of behaviours, language, and actions of an intact cultural group in a natural setting over a prolonged period. The specific case studies are a design of inquiry found in many fields, especially evaluation, as they comprise of

the researcher developing an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals. In addition, the cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period (Stake, 1995; Aberdeen 2013). It is fascinating how, qualitative and quantitative research can be brought together and combined through one system: the mixed-methods design.

The mixed-methods were defined by Morse and Niehaus (2008) as "*the incorporation of one or more methodological strategies or techniques drawn from a second method, into a single research study, to access some part of the phenomena of interest that cannot be accessed by the use of the first method alone*" (p.9).

It is useful to bear in mind how qualitative and quantitative data differ from each other: qualitative data tends to be open-ended without predetermined responses whilst quantitative data usually includes closed-ended responses such as found on questionnaires or psychological instruments. These methods are relatively new as they were only introduced and studied between the mid and the late 1980s. Remarkably, they only firstly appeared as a method to analyse psychological traits in Campbell and Fisk's studies in 1959, until then, only quantitative measures had been exercised. However, it was on account of to this first research that other researcher started to collect multiple forms of data, such as observations and interviews (qualitative data) through traditional surveys (Sieber, 1973). Early thoughts about the value of multiple methods—called mixed-methods—resided in the idea that all methods had bias and weaknesses, and the collection of both quantitative and qualitative data neutralized the weaknesses of each form of data. In this context, triangulating data sources was born: a means for seeking convergence across qualitative and quantitative methods (Jick, 1979). By the early 1990s, mixed-methods turned toward the systematic convergence of quantitative and qualitative databases, and the idea of integration in different types of research designs emerged. Procedures for expanding mixed-methods developed as follows:

a) Ways to integrate the quantitative and qualitative data, such as one database, could be used to test/prove/examine the accuracy (validity) of the other database.

b) One database could help explain the other database, and one database could explore different types of questions than the other databases.

c) One database could lead to better instruments when instruments are not well-suited for a sample or population.

d) One database could build on other databases, and one database could alternate with another database back and forth during a longitudinal study.

Since then, the designs have developed and annotations have been added to help the reader understand. Also, new challenges to work with the designs have been conceived (Creswell et al., 2011). Today, practical issues are being discussed regarding examples of "good" mixed-methods studies and evaluative criteria such as: the use of a team to conduct this model of inquiry, and the expansion of mixed-methods to other countries and disciplines. Although many designs exist in the mixed-methods domain, this book will focus on the three primary models found in social sciences today:

- *Convergent parallel mixed methods* are a form of mixed-methods design in which the researcher converges or merges quantitative and qualitative data to provide a comprehensive analysis of the research problem. In this design, the investigator typically collects both forms of data at roughly the same time and then integrates the information in the interpretation of the overall results. Contradictions or incongruent findings are explained or further probed in this design.

- *Explanatory sequential mixed-methods*, whereby the researcher firstly conducts quantitative research, (he or she) then analyses the results, and finally builds on these to explain them in more detail through qualitative research. It is considered *explanatory* because the initial quantitative data results are explained further with the qualitative data. Equally, it is considered *sequential* because the initial quantitative phase is followed by the qualitative phase. Furthermore, this type of design is popular in fields with a strong quantitative orientation (hence the project begins with quantitative research), but it presents challenges in identifying the quantitative results to further explore and in the unequal sample sizes for each phase of the study.

- *Exploratory sequential mixed-methods* are the reverse sequence from the explanatory sequential design. In the *exploratory sequential* approach, the researcher first begins with a qualitative research phase, exploring the views of participants. The collected data is then analysed, and the information is used to construct a second quantitative phase. The qualitative phase may be used to assemble an instrument that best fits the sample under study, to identify appropriate instruments to use in the follow-up quantitative phase or to specify variables that need to go into a follow-up quantitative study. Particular challenges to this design reside

in focusing on the appropriate qualitative findings to use and the sample selection for both phases of research.

 These basic models can then be used in more advanced mixed-methods strategies. *Transformative mixed methods* are a design that uses a theoretical lens drawn from social justice or power as an overarching perspective within a design that contains both quantitative and qualitative data. The data in this form of study could be converged or it could be ordered sequentially with one building onto the other. An embedded mixed methods design also involves either the convergent or sequential use of data, but the core idea is that either quantitative or qualitative data is enclosed within a larger design (e.g., an experiment) and the data sources play a supporting role in the overall design. A multiphase mixed-methods design is common in the fields of evaluation and program interventions. In this advanced design, concurrent or sequential strategies are used in tandem over time to best understand a long-term program goal.

Considering the described methods, with regards to the specific research of this thesis, the *exploratory mixed-methods* is the most suitable approach to conduct this study and analysis concerning serious games on sustainability issues. In the following paragraphs, the crucial steps of the research, which present similarities with the exploratory methods, will be explained. In the following paragraphs, the accordance of the exploratory methods in relationship to this research, will be explained throughout the specific steps of its process.

1.3.2.1 Exploratory sequential mixed methods: proposing analytical flow chart

As mentioned in the previous sequence, the exploratory sequential mixed-methods propose a process consisting of sequential steps. According to this, my work starts with a qualitative research phase and explores the views of authors and scholars through the literature review. Subsequently, the data is further analysed, and the gathered results generate a second, quantitative phase. The outcomes of the qualitative research phase become useful to build an instrument that best fits the sample under study. The instrument in question that I would like to propose is an analytical flow chart. It is designed to be tested on serious games with the aim of identifying possible correlations between game elements and sustainable goals.

The analytical flow chart is realized according to i) the studies of linkages among the SDGs conducted by the Joint Research Center- JRC and resumed in the

"Interlinkages visualization tool"[1], and ii) the studies of Werbach and Hunter (2012) for the identification and description of game mechanics.

The Interlinkages visual tool shows all levels of presentation in which the user can choose between the visualization of synergies or trade-offs. Consequently, by hovering the mouse over the circle on the left the user finds an instant visualization of the interlinkages of specific goals and targets on a disaggregated level as provided by the literature. By selecting the "Sankey button" the user is sent to the visualization of the interlinkages for the respective goal. This tool will be described in more detail in Chapter 3.

The identifications and correlations of game elements in sustainable goals are defined in the analytical flow chart through two levels of interpretation. This choice was made on the basis of the limited information available to the market on the SDGs covered by the games. The few classifications and/or databases that handle such information contain, at most, the name of the SDG concerned. It is therefore almost impossible to find more detailed information on the targets or indicators that define the SDG itself. It was decided to propose such analytical flow chart to try to fill this gap by exploring in more detail which aspects of the SDG in question are covered.

In this respect, the first level concerns the identification of game elements based on specific SDGs and respective targets. On the other hand, the second one regards a more detailed identification mainly according to SDG11-Sustainable cities and communities targets and indicators but occasionally also to SDG 12- Responsible consumption and production and SDG 7- Affordable and Clean Energy (both with very strong references to goal 11). The aim is indeed to find connections with SDG 11 or SDG12 and other goals through positive or negative interlinkages.

In order to identify these connections, the Interlinkages visualization tool allows an immediate and rapid identification of possible synergies or trade-offs. In a second step these links are subsequently confirmed, cancelled or new ones are added, depending on how the element has been developed throughout the game.

However, due to game mechanics, players' engagement is supported, and actions are encouraged within games. Chapter 2 (Paragraph 2.1.1.) provides a more detailed explanation of this statement. However, in order to facilitate the reading and understanding of the analytical flow chart the 10 principal game mechanics features are listed here (Werbach and Hunter, 2012):

- Challenges, puzzles or other tasks that require effort to solve
- Chance, elements of randomness
- Competition, one player or group wins, and the other loses
- Cooperation, players must work together to achieve a shared goal
- Feedback, information regarding the player's performance

[1] https://knowsdgs.jrc.ec.europa.eu/interlinkages-visualization

- Resources Acquisition, obtaining useful or collectible items
- Rewards, benefits for some action or achievement
- Transactions, trading between players, directly or through intermediaries
- Turns, sequential participation by alternating players
- Winning states, objectives that make one player or group the winner-draw and loss states related concepts

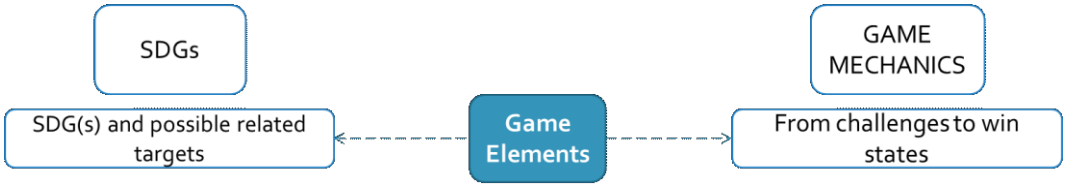

Figure 4_ The analytical flow chart proposed as an instrument to classify game elements according to game mechanics and SDGs

*Figure **4*** shows the analytical flow chart designed for the first level of interpretation, taking into consideration game elements according to compatible SDGs and game mechanics. Subsequently, *Figure **5*** shows the analytical flow chart applied for the second reading level of interpretation to identify possible synergies or trade-offs among the goals covered in the analysed game element.

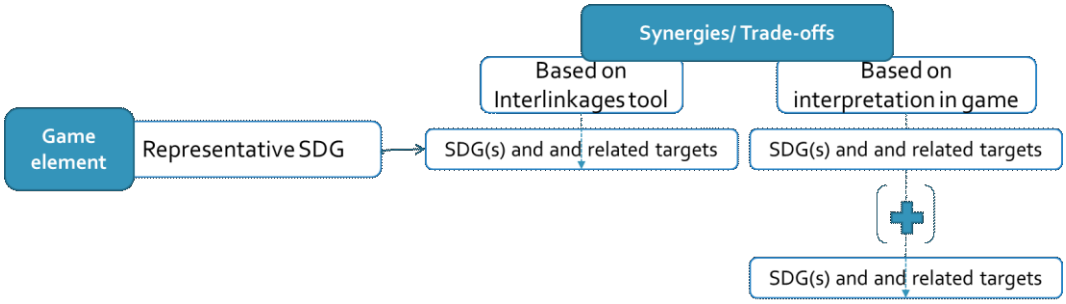

Figure 5_ The second interpretative level of the analytical flow chart for classifying synergies or trade-offs between the goals dealt with by the game element

In this thesis, the analytical flow chart will be tested twice. The first test will be carried out on three serious games identified following the new classification personally conducted in 2018 on sustainable games. These serious games are: Urban Climate Architect[2], Energy City[3] and New Shores[4]. The first two are available online in single-player mode. The third is an online multiplayer game and requires the presence of a moderator to play. I had the opportunity to play New

[2] https://www.clisap.de/stadtklimaarchitekt/
[3] https://assets.jason.org/
[4] https://newshores.socialsimulations.org/

Shores while attending the Summer School Polito-UCLA of "Learning by game creation: cultural heritage, cities, and digital humanities", at Politecnico di Torino in September 2019. The second test, instead, will be carried out on the winning serious games of the Talenti Polito Challenge: Patent, Polinks and iPolito. The winning games have been created by university students involved in the challenge, they are multiplayer board games repurposed on the online platform of Tabletopia due to Covid-19 pandemic.

Table 2_ Qualitative, Quantitative, and Mixed Methods Approaches according to (Creswell 2014)

Tend to or typically…	Qualitative approaches	Quantitative approaches	Mixed methods approach
▪ Use these philosophical assumptions ▪ Employ these strategies of inquiry	▪ Constructivist/ transformative knowledge claims ▪ Phenomenology grounded theory, ethnography, case study, and narrative	▪ Postpositivist knowledge claims ▪ Surveys and experiments	▪ Pragmatic knowledge claims ▪ Sequential, concurrent, and transformative
▪ Employ these methods	▪ Open-ended questions, emerging approaches, text or image data	▪ Closed-ended questions, predetermined approaches, numeric data	▪ Both open and closed-ended questions, both emerging and predetermined approaches, and both quantitative data and analysis
▪ Use these practices of research as the researcher	▪ Position him-or herself ▪ Collects participant meanings ▪ Focuses on a single concept or phenomenon ▪ Brings personal values into the study ▪ Studies the context or setting of participants ▪ Validates the accuracy of findings ▪ Makes interpretations of the data ▪ Creates an agenda for change or reform ▪ Collaborates with the participants	▪ Tests or verified theories or explanations ▪ Identifies variables to study ▪ Relates variables in questions or hypothesis ▪ Uses standards of validity and reliability ▪ Observes and measures information numerically ▪ Uses unbiased approaches ▪ Employs statistical procedures	▪ Collects both quantitative and qualitative data ▪ Develops a rationale for mixing ▪ Integrates the data at different stages of inquiry ▪ Presents visual pictures of the procedures in the study ▪ Employs the practices of both qualitative and quantitative research

Chapter 2

Gamification and Serious Games

Chapter 2 mostly analyses the literature review of gamification and serious games. The first section of this chapter introduces a general overview of the gamification world. In particular, it starts by explaining the first definition of the term 'gamification' provided by Deterding et al. (2011) and continues through the studies of Zichermann and Cunningham (2011), Werbach and Hunter (2012), and Maestri et al. (2015) in regards of characteristics, uses, benefits and contexts of application. Furthermore, this overview pays particular attention to the hierarchy of game elements, which are composed by game dynamics, mechanics and components. The focus is especially on game mechanics, as it plays a crucial role within the analytical flow chart on serious games proposed and tested in this research.

The following paragraphs completely focus on serious games. Serious games, as will be further explained, are to all intents and purposes real games with the specific aim to educate.

Through the analysis of the literature, the origins of the term and the different definitions that have been given to it over the years will be defined. In this regard, it is important to underline that the expression “serious game” tends to be replaced by similar phrases that retain the meaning. The most common are “educational

game", "game-based learning", "digital game", "business game", "applied game", "edutainment game" or "simulation game".
However, the findings from studies on the characteristics and uses of serious games show that they can be applied to different contexts such as military, political, religious, wellbeing, mathematical, physical, educational and also for urban planning, city design and architectural design.
Above all, the most valuable purpose is their use in educational areas concerning sustainable development. Although serious games are widely popular within education, literature review shows that they are still not commonly employed in the specific field of sustainability. Hence, the need to focus research on the issue of education for sustainable development, which will be addressed in Chapter 3.
The themes of education and learning are therefore an integral part of serious games. For this reason, certain paragraphs in this thesis will deal with two key knowledge transmission modes: "learning by playing" and "learning by making". Through further analyses of these methods, an attempt to answer the following question is made: *which are the most successful methods or strategies which assess the effectiveness of learning by playing serious games?*
By analysing the different strategies, various frameworks, methods and models will be explained. These will be useful to define appropriate new questionnaires and surveys to assess the effectiveness of learning by playing and game-making, especially in regards of Talenti Polito Challenge.

2.1 An overview of gamification

According to Deterding et al. (2011) "Gamification is the use of *game elements* and *game design techniques* in *non-game contexts*". This first definition develops throughout three sections. The first concerns the "game element", the second consists in "game design techniques", and the third "non-game context". *Game elements* concern characteristics and properties specific to each game, setting up the specifications of games. For instance, considering the game of chess, game elements consist in the game pieces and the rules of the game. In this case, such notions in regards of chess will be the game's rules: to capture pieces, players must jump and turn their pieces on the board, until reaching the opposer's last row on the board and take on the king. It is key to bear in mind that game elements can involve objects (pieces), relationships/actions among/between pieces (jumping), but also abstract concepts embedding rules (making a doble checkers). Games elements are essential to the success of a good game. These elements help design games in which players are thoroughly engaged, allowing to achieve better and more compelling business practices.

Moreover, gamification refers to "using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems" (Kapp, 2012). In other words, the focus is on properties of gamification that can be used to stimulate learning. Although there are several definitions of gamification (Deterding et al., 2011; Marczewski, 2013, Perrotta et al., 2013; Simões et al., 2013; de Sousa Borges et al., 2014), there is a substantial common agreement entailing they are a method/system which applies game features into non-game settings. These game features can be elements, mechanics, frameworks, aesthetics, thinking, metaphors or abstract concepts.

Gamification is generally employed to tackle many issues such as maintaining students' involvement and interests, engaging users and encouraging them to achieve more ambitious goals and, finally, encouraging the use of computer and video games in everyday life (Faiella and Ricciardi, 2015).

Furthermore, according to Cook (2013), any case or situation that presents some of the following assumptions can be turned into a game or be gamified: activities that can be learned, user's actions to be measured and feedback that can be timely given to the user (González and Carreño, 2014). Gamification can combine different elements in order to create suitable learning experience for the players, by designing techniques. Normally, *game design techniques* consist in a series of actions and skills that move game rules, whilst involving compelling features such as entertainment, challenges, cooperation, leadership and education features. Moreover, game design usually does not include a list of components or step-by-step instructions.

Based on the literature some related works (Fitz-Walter, Tjondronegoro and Wyeth, 2011; Decker and Lawley, 2011) show that the use of game techniques has increased, in the last decade, in higher education contexts (González and Carreño, 2014). In fact, they have been proven a useful learning tool as they help improve mental flexibility, problem solving skills, competition or collaboration among students.

Finally, gamification operates in a *non-game context*, which can be differentiated between internal, external, or behaviour change situations. Despite their differences, all types are equally involved in real-world business or social impact goals. This way, gamification can produce measurable results. According to Werbach and Hunter (2012) these contexts, illustrated in *Figure 6*, are further defined as follows:

External: enquires the organization people belong to. Generally, this application is for existing or potential customers. The applications in this category are driven by marketing objectives such as marketing, sales and customer engagement. In this context, the role of gamification is to find and fix a connection, creating a

relationship between business (industries or societies) and customers, through actions and products. Usually, badges and points can be used to describe the player's profile, perhaps an employee, who will be distinguished more easily from external collaborators.
Internal: this approach is for people that are already within a company or a society, employees for instance. Internal gamification, - also known as "enterprise gamification"- involves HR, productivity enhancement and crowdsourcing. It is advantageous for companies, helping improve productivity within the organisation to foster innovation, enhance camaraderie, or otherwise derive positive business results through employees. Start-ups and small societies are clear examples that benefit from these systems, increasing their productivity by applying game design techniques. Moreover, internal gamification may be defined throughout two main attributes: the players, identified within a community (company, industry, society and so on) and motivation, what contributes to determining the behaviour of an individual, or even of a community. These elements for instance, allow companies to know their employees and guide interactions with the existing team management, providing rewarding structures through motivational level.

Behaviour change: is an application for people who aspire to create something new. The key aspect of this application is certainly motivation, which plays a central role in potentially changing habits and behaviour, encouraging the practice of playing/encouraging engagement.
In general, this kind of approach is for serious games, as it concerns people and it searches for ways to encourage engagement in specific situations. Specifically, it involves themes such as health and wellbeing, sustainability and personal finance. For instance, they may encourage better health choices, or to redesign classrooms for students to provide a better learning environment, or also move people's interest towards sustainability issues. When behaviour change is applied, positive social financial decisions are made, better school classrooms and activities are arranged, or even more efficient educational systems are initiated.

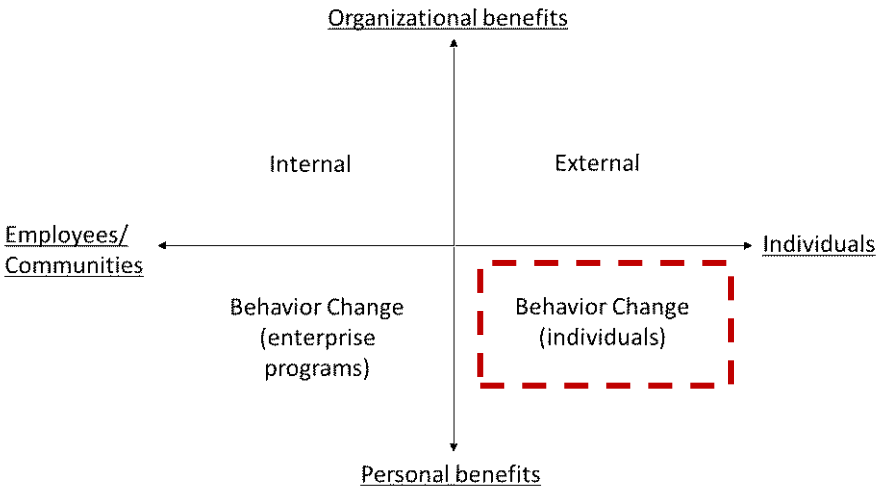

Figure 6_Relationship between non-game contexts (Werbach & Hunter, 2012)

The aim of this thesis, focuses on non-game contexts for individual behaviour change, being typical applications of serious games. During the second half of the 20th century, games started to be used for serious/meaningful/practical/constructive purposes (or "serious games") (Abt, 1987); firstly, used for military reasons, they were then applied in education and business settings (Deterding et al., 2011). The term serious game denotes games designed to convey learning through play. For this reason, game elements play a critical role in the realisation of serious games. For instance, if people watch a basketball game, they will be constantly attracted and fascinated by the intensity and speed of the game. Game elements are what draws the attention to the game, making it engaging, fascinating and compelling to watch. In the context of basketball, the game elements involved are: the ball, the whistles, the court, the relationship between the objects, the behaviour of the players and the rules that have to be taken into account, and interestingly, the possibility of measuring everything through points.

There are no ludic activities which can be realized without rules to control the game elements.

Therefore, serious games must be developed through rules and they must be based upon the relationships between game elements. Above all, such conventions must be respected to ensure that players learn new skills while playing and entertaining themselves. As competitive and attractive serious games need to be developed through a game design approach, and, thus game elements, what are the most suitable categories of game elements? According to Werbach and Hunter (2012), three different categories of game elements must be identified, and they are dynamics, mechanics and components. The following paragraph is entirely dedicated to the description of these categories.

2.1.1 The pyramid of game element

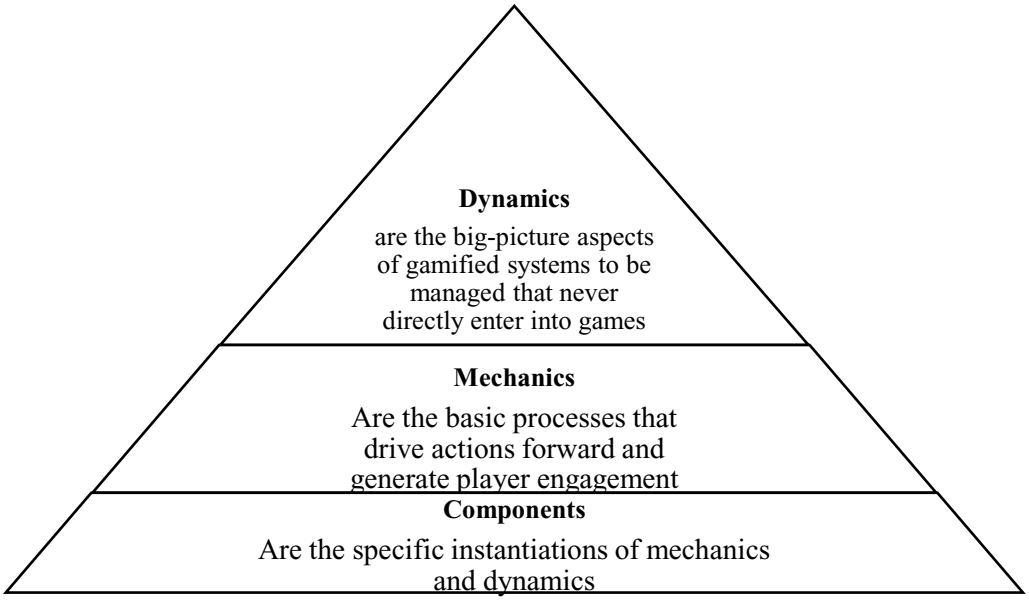

Figure 7_ The pyramid of game element hierarchy, an adaptation from (Werbach & Hunter, 2012)

According to the framework of Hunicke, LeBlanc, and Zubek (2004) the following studies conducted by Werbach and Hunter (2012), it is possible to resume the classification and distinction of the three elements of a gamified system as follows:

I. *Dynamics* concern conceptual aspects that, for their nature, are not directly inserted within a gamification system, but help to build/play the game itself. They consist of: a) bonds and limitations; b) emotions, such as curiosity and competitiveness; c) storylines: d) progression of players; e) relationships comprising of social interactions;
II. *Mechanics* support processes that push the action and determine the involvement of players within games. They consist of challenges to overtake, chances, competition, feedback, resources purchase, rewards and different game rounds;
III. *Components* are the core essence of games as they can take rules inside games' clockworks, for instance in an avatar or players design, results and achievement reachable through objects or point collections, competitions or internal game conflicts, unlocked contents and gifts.

The *dynamics* are the concept which shapes the implicit structure of the game. Combined with game mechanics they stimulate motivation and engagement in the learning process. Generally, they may consist of constraints, narrative, progression and relationship as described in *Table 3*. Furthermore, they are one of the three

elements of a gamified system that may be managed without directly entering games.

Table 3_ List of main element of Dynamics (Werbach & Hunter, 2012)

Dynamics	**What they are and examples**
Constraints	Limitation or forced trade-off
Emotions	Such as curiosity, competitiveness, frustration, happiness
Narrative	A consistent, ongoing storyline
Progression	The player's growth and development
Relationship	The social interactions that generate feelings of camaraderie, status, altruism

Mechanics stimulate player engagement and drive actions into the game. They are an essential to the development of the game and Werbach and Hunter (2012) identified 10 mains used game mechanics, which are most commonly used (summarized and illustrated in *Table 4*). Chapters 4 and 5, will emphasise on game mechanics, providing further explanations, as they are one of the key components of the analytical flow chart.

Since game mechanics consist in the practical implementation of the actions developed in the game, it will be interesting to analyse theme through the analytical flow chart, understanding how the concepts related to sustainability are put into practice.

Table 4_ List of main elements of Mechanics (Werbach & Hunter, 2012)

Mechanics	**What they are and examples**
Challenges	Puzzles or other tasks that require effort to solve
Chance	Elements of randomness
Competition	One player or group wins, and the other loses
Cooperation	Players must work together to achieve a shared goal
Feedback	Information regarding the player's performance
Resources Acquisition	Obtaining useful or collectible items
Rewards	Benefits for some action or achievement
Transactions	Trading between players, directly or through intermediaries
Turns	Sequential participation by alternating players

Win states	Objectives that make one player or group the winner-draw and loss states are related concepts

In contrast to game elements, components represent more specific forms that mechanics and dynamics can acquire. According to Zichermann and Cunningham (2011), the most important components are:
a) Scores, the measure for evaluating players' results and comparing them in a way to promote their continuous involvement in games;
b) Badges, often replaced by "achievements", are a virtual representation of results gained by players (for instance at the end of a level);
c) Levels, components of every type of game, which divide the game into different layers according to the difficulties the player faces;
d) Leader boards, used to collect players' results or scores, allow to assess players and encourage them to improve and win the game;
e) Challenges, real issues and tasks to be faced in the game. By facing challenges, players test their individual skills.
The following table (*Table 5*), presents Werbach and Hunter's (2012) 15 best-known and most widely used game components, summarising them as follows.

Table 5_ List of main elements of Components (Werbach & Hunter, 2012)

Components	What they are and examples
Achievement	Defined objectives
Avatars	Visual representation of player's characters
Badges	Visual representation of achievement
Boss fights	Particularly hard challenges at the culmination of a level
Collections	Sets of items or badges to accumulate
Combat	A defining battle, typically short-lived
Content Unlocking	Aspects available only when players reach objectives
Gifting	Opportunities to share resources with others
Leader boards	Visual display of player's progression and achievement
Levels	Defined steps in player progression
Points	Numerical representations of game progression
Quests	Predefined challenges with object and rewards
Social graphs	Representation of players' social network within the game
Teams	Defined groups of players working together for a common goal

Virtual Goods	Game assets with a perceived or real-money value

The most popular components are *points, badges and leader boards*, better known in the literature by the acronym PBL (González and Carreño, 2014).

Points represent a system of keeping score that players accumulate throughout the course of the game. They are generally used to encourage players to play better, collecting as many points as possible. Werbach and Hunter (2012) have identified six different ways in which points are used in gamification: points effectively keep score; points to determine the win state of a gamified process; points that create a connection or link between progression in the game and extrinsic rewards; points provide feedback; points can be an external indicator of the level of progress achieved, and points provide data for the game designers. The correct use of the score system depends on the objectives that players, or game designers, aim to achieve by the end of games.

Badges are visual achievements that players obtain collecting a large number of points. Often, terms like achievement and badges are used interchangeably, to mark a certain score. For instance, in online games, they represent a moment for celebrating players' step goals, such as when a level is passed. According to Antin and Churchill (2011), a well-designed badge system has five motivational characteristics as:

a) badges can positively impact the users' level of motivation to strive harder;

b) badges provide guidance within the system and present a shorthand of what the system is supposed to achieve (this is a crucial feature to induce and implement the users' involvement with the system);

c) badges are means to evaluate what players care about and what they have performed;

d) badges represent the game journey of players, operating like a virtual status symbol, and

e) badges can immediately identify players in an online community, serving, for example, as a tribal marker.

Finally*, levels/leader boards* show the player's (o players') progression. Generally, they are applied to online games and video games, and represent the capacity of players to overcome challenges and progress in the game. Obtaining points and achieving higher levels are directly proportional: the higher the number of points a player can obtain, the higher the levels achieved. In several apps and online games, there are thousands of different levels that players can achieve. For instance, in Candy Crush the difficulty's level grows gradually with a total number of almost 3000 levels. Usually, game designers work to constantly create more advanced levels, in order to satisfy the players' demands. Levels or leader boards give context to progression in a way that points or badges can't. Leader boards make the player's

performance public. However, they are slightly controversial: in the right context, leader boards can be powerful tools and motivators, but, on the other hand, they can also demotivate the player. The construction and the use of levels or leader boards requires several details.

Taking into account the three elements of a gamified system (dynamics, mechanics and components) described above, it should be specified that these elements do not constitute the game in itself. Rather, games are built upon the interactions of these elements, in order to provide the players with fun and engagement. The combination of the three elements can generate ideas for realizing real games especially helping the actualization of new and interesting gamification projects.

Game design plays a key and important role in the realisation of a good final product. A good design indeed consists of combining the 3 elements in perfect synchrony while maintaining a good balance between the parts involved.

Regarding this matter, Werbach and Hunter (2012) stated that a good design for a gamification project must take account of six aspects, each of which beginning with letter D:

- Define business objectives within games;
- Delineate the behaviours of target players and what serious games can stimulate by playing;
- Describe the target of the players, relative typologies and motivations;
- Device activities and sequences of games;
- Don’t forget to have fun;
- Deploy appropriate tools.

Trying to summarize the previously mentioned descriptions of gamification and game elements, a brief review shows that “gamification” has developed within a rich bed of interacting trends and traditions. Game design work already entails some potentially competing, parallel, or overlapping concepts.

In the field of game studies, gamification can be seen as a further development of the repurposing and extension of games beyond entertainment. The elements constituting gamification form the basis of other games that belong to the “ludification of culture” (Deterding et al., 2011) as shown in *Figure 8*. Gamification and serious games are not the same thing, they belong to the sphere of “using games”, but differ in some characteristics and purposes. While serious games meet all the necessary and sufficient requirements to be considered games, gamified applications simply use different game design elements. Seen from the designer's perspective, what distinguishes 'gamification' from 'normal' entertainment games and serious games is that they are built within a system that includes elements from games, not an actual 'game' (Deterding et al., 2011). From the user's point of view, it is precisely the involvement of design elements from games in such systems - that

can be implemented and experienced as “real games”: playful, ludic or otherwise that distinguishes them.

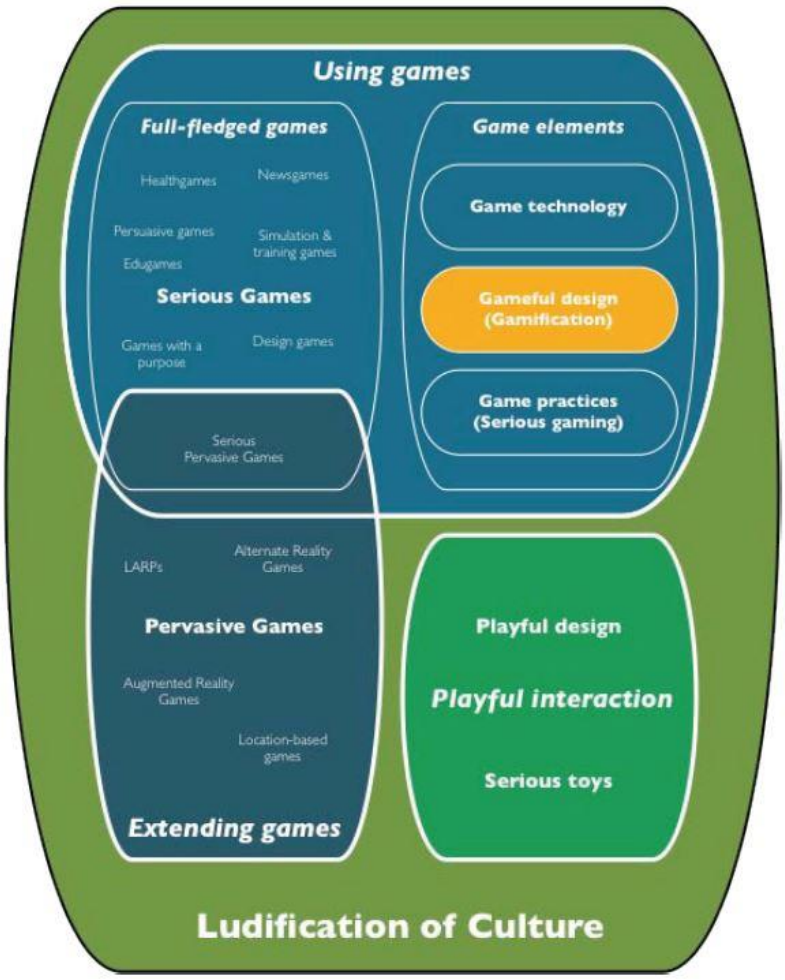

Figure 8_ Contextualizing “gamification” and serious games in the field of game studies (Deterding et al., 2011)

The use of games in non-game contexts falls into full-fledged games (serious games) and game elements, which can be further differentiated into game technology, game practices, and game design. Moreover, serious games and “pervasive games” or “game-based learning” are often confused. These expressions, which seem to indicate the same type of games, refer to other, very precise categories. In this regard, in addition to the serious games’ phenomenon, new game genres have emerged that have expanded the traditional limits of games, bringing games into new contexts and situations (Deterding et al., 2011) these are commonly known as pervasive games as they have “one or more salient features that expand the contractual magic circle of play spatially, temporally, or socially” (Montola, Stenros and Waern, p. 12, 2009). According to the definition of Huizinga

(1955) play is defined when the participants agree that some activities in some places by the players are interpreted playfully as a part of the game instead of ordinary life. Breaking these boundaries of game is not an original idea, but the systematic approach on it makes pervasive gaming a novel form of gaming (Montola, 2009). Pervasive games consciously exploit the ambiguity of expanding beyond the basic boundaries of the contractual magic circle. The expansion dimension could be spatial, temporal or social. Spatial expansion means that the socially constructed location of games is unclear or unlimited. Games such as Songs of "North" or "I Love Bees" have used cityscape as playground, expanding locally and even globally. The spatial expansion only applies to games that are affected by the player's spatial context, usually in relation to physical places or to other players (Montola, 2009). Examples of pervasive games are: location-based games that bring players into public spaces, augmented reality games that use digital devices to overlap game representations on the environment, persistent games that continuously run in and out throughout the day, and alternate reality games which "take the substance of everyday life and weave it into narratives that layer additional meaning, depth, and interaction on top of the real world" (Montola, Stenros and Waern, p. 37, 2009). *Table 6* shows the main definition and description of all these terms, which are often mistakenly interchanged.

Table 6_ Definitions and descriptions of the 4 keywords (gamification, serious games, game based-learning and pervasive games) most used by scholars to talk about applications in the game field

Type of game	Definition	Description
Gamification	"Gamification is the use of game elements and game design techniques in non-game contexts" (Deterding et al., 2011) Hutoari and Hamari (2012), argued that the goal of gamification is not merely "having fun", but overall value creation, which can also come in the shape of having cognitively demanding tasks and broaden the horizon of activities.	It has its roots in the psychology of playing, in-game design and in-game thinking, such a restricted view is unsatisfying, as potential benefits are cut short and critique is easy at hand.
Serious games	Serious game is a "game that can be played seriously or casually by people. We are concerned with serious games in the sense that these games have an explicit and carefully	Serious games are games in which the only objective is not just entertainment but also to teach something new to the players involved.

	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 not be, entertaining" (Abt C., 1987)	
Game based-learning	Game-based learning (GBL) is a type of gameplay that has specific defined learning outcomes. Generally, game-based learning is designed to balances knowledge communication with gameplay and the player's ability to retain and apply learnt knowledge to the real-world problems.	Game-based learning has a major focus on learning. It describes an approach to teaching, where students explore a relevant aspect of games in a learning context designed by teachers. Teachers and students collaborate to add depth and perspective to the experience of playing the game.
Pervasive games	"…game and life bleed together so that game becomes heavy with the reality of life, and life becomes charged with the meaning of the game (Montola, Stenros and Waern 2009)	One of the main characteristics of this game typology is that the game pervades life and life becomes the game

According to the aims of this thesis and after clarifying what gamification is and how it differs from other game applications, the next sections will narrow their focus to serious games only. The choice to study and use serious games instead of other game applications is due to several factors. Serious games, as I will further explain in the next sections, are educational learning tools, as they can impart knowledge and concepts to the player during the game phases. They are also applicable to any kind of context. They are suitable for all ages and can be developed in any mode, online, board, card, etc. Thanks to these multi-faceted features, it was possible for university students at the Politecnico di Torino to develop new serious games completely online and remotely due to the Covid 19 pandemic (Chapter 5).

2.2 Serious games

The first definition of serious games was given by Clark C. Abt (1987) in his book "Serious games". Clark defined games a "particular way of looking at something, anything". In addition, he stated that "reduced to its formal essence, a game is an activity among two or more independent decision-makers seeking to achieve their

objectives in some limiting context. A more conventional definition world says that a game is a contest with rules among adversaries trying to win objectives". The games described in "Serious games" book (1987) mainly refer to board and card games but the definitions of Abt are also suitable to virtual and computer games (Bellotti, Berta and De Gloria, 2017).

According to Abt theory, Costikyan (2002) defined a game as "a form of art" in which the participants, officially known as *players*, can make decisions to control resources through game actions and activities attempting to achieve the game's goal.

The terminology of "serious games" has become more popular since 2002, with the establishment of the Serious Game Initiative lead by David Rejeski and Ben Sawyer in the US, and taken up in Europe by the creation of the Serious Games movement, particularly prominent in the UK (Bellotti, Berta and De Gloria, 2017).

Moreover, Zyda (2005) provided another fascinating insight affirming that serious games could also be identified as a mental process, played also through electronic devices following specific rules, using "entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives". Accordingly, serious games can accommodate multiple learning aims, so they can be practiced in numerous contexts, targeting all age groups (Mouaheb, et al., 2012). Also, they can be employed as teaching tools, providing information and entertainment through the means of a communication technology system. To clarify, the goal of a serious game consists in the reduction of problem-complexity to a level of such abstraction, that allows the players to easily interact with (de Heer et al., 2010).

Taking into account all the main definitions of serious games, the need to clarify the adjective "serious" emerges. The definitions reported in *Table 7*, do not consider serious games a playful practice that limits entertainment. Instead, the adjective "serious" entails that these games will convey fruitful knowledge, communicating it through the entertainment of the game. From the earliest definitions, "serious" implies a study relating to matters of great interest and importance, raising questions not easily answered, and possibly causing severe consequences (Abt, 1987).

The full expression "serious games" is sometimes perceived as an oxymoron because it combines the seriousness of thought and problems to the experimental and emotional freedom of active play. On the other hand, according to other researchers, the adjective "serious" placed next to "game" would give the expression a tautological meaning. Armenia et al.[5] argue that the very act of playing

[5] Armenia S., Barnabé F., Ciobanu N., Kulakowska M. Interactive "boardgame-based" learning environments for decision-makers' training in managerial education, White paper;

is a serious activity and that the further definition of 'seriousness' brought out by the adjective would affirm something already defined as true. They prefer to argue that "the use of "serious" undermines (some could even say that it "offends") the already very serious nature of gaming". For this reason, they proposed the use of Interactive Learning Environments (ILEs), instead of serious games, as "learning laboratories that help to sustain processes of learning not achievable in real life" (Armenia et al., 2019).

About learning aspect, according to Michael and Chen (2006), serious games are an ideal and highly efficient tool for education, which can be transformed in different forms and ways, whilst always holding a higher purpose rather than solely focusing on entertainment.

In this regard, educational contexts seem to be the most suitable for the use of serious games. The use of games in schools is already highlighted in Abt's early studies, showing how games may deal with important outselling issues, and how they are able to analyse issues in almost all academic and intellectual fields: "Education, analysis, and evaluation are all rich fields for the use of the serious game. In education, games are used by teachers for classroom instruction in social studies, sciences, and humanities, and for guidance outselling" (Abt, 1987). Further in this Abt's text, he also touched upon the possibility to apply this tool to assess matters such as regional transportation plans or public responses to the environment and many issues related to urban sustainability. One of the main strengths of serious games is that they support effective decision processes by acquiring data directly from people, through a very simple approach based on entertainment. Games are motivating, they provide immediate feedback in real time, they can be adapted to the level of the user, they encourage distributed learning, and they can also be applied for various other teaching purposes (Gee 2003; Gentile 2011). According to Ouarachi et al. (2018), education embraces serious games because teachers have finally recognised their potential. Another interesting consideration can be made in regards of the use of games, considering what numbers and game trends may be prevalent. Statista (2018) claims that the market of serious games is one of the fastest-growing areas in educational media and it is expected to grow from 3.2 billion U.S. dollars in 2017 up to 8.1 billion in 2022.

Serious games can play an important role allowing players to live unique experiences that would be difficult to experience in real life, for reasons as various as economic or social. For instance, they can create awareness and promote attitudinal and behavioural changes on sustainable issues simulating the work of a mayor in the administration of a more sustainable city. In the game experience, possible actions and tasks would include controlling pollution, producing

(http://sustainerasmus.eu/wp/interactive-boardgame-based-learning-environments-for-decision-makers-training-in-managerial-education/ _ viewed on 8th October 2021)

sustainable energy and looking after the well-being and health of citizens (Ouariachi, Olvera-Lobo, and Gutiérrez-Pérez 2018).
In this regard, serious games are found to be effective tools applicable all sorts of researches and practical fields (such as education, management, industries, and health care) even if they are currently not yet considered a popular tool to spread knowledge on urban sustainability.

Table 7_ List of the most important definitions of serious game from 1987 to present date

Year	Author	Definition
1987	Abt, Clark C. *The Serious Game.* New York: The Viking Press	"Games may be played seriously or casually by people. 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 not be, entertaining" "Reduced to its formal essence, a game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context. A more conventional definition world says that a game is a contest with rules among adversaries trying to win objectives"
1999	Stoll, C. *High-tech heretic: Reflections of a computer contrarian*. New York: First Anchor Books.	"…direct students away from reading, away from writing, away from scholarship. They dull questioning minds with graphical games where quick answers take the place of understanding, and the trivial is promoted as educational. They substitute quick answers and fast action for reflection and critical thinking […] Turning learning into fun denigrates the most important things we can do in life: to learn and to teach. It cheapens both process and product: Dedicated teachers try to entertain, students expect to learn without working, and scholarship becomes a computer game."

2002	Costikyan G. *I have no words and I must design.*	"…a game as a form of art in which participants, termed players, make decisions to manage resources through game tokens in the pursuit of a goal. One of the most interesting components of these two definitions is the acknowledgement that a game is an activity in which players make decisions''.
2005	Zyda M. From *visual simulation to virtual reality to games*. Computer, 38(9), 25-32.	"Serious games have more than just story, art, and software, however. (…) They involve pedagogy: activities that educate or instruct, thereby imparting knowledge or skill. This addition makes games serious". "Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."
2006	Michael D. R and Chen S. L. *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade.	"A serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment" " …the game is a voluntary activity, obviously separate from real life, creating an imaginary world that may or may not have any relation to real life and that absorbs the player's full attention. Games are played out within a specific time and place, are played according to established rules, and create social groups out of their players."
2007	Sawyer B. *Serious games: Broadening games impact beyond entertainment*. In Computer Graphics Forum (Vol. 26, No. 3, pp. xviii-xviii). Oxford, UK: Blackwell Publishing Ltd.	"Any meaningful use of computerized game/game industry resources whose chief mission is not entertainment"
2008	Quinn, C., Neal, L. (2008). *Serious Games for serious topics.* eLearn Magazine,(3).	"When a serious game is done effectively, it engages the learner's emotions and brain in a coherent experience that leaves them with new attitudes, understandings, and/or skills".

2009	Liukkonen, T. N. VIPROSA–game-like tool for visual process simulation and analysis. In Design and Use of Serious Games (pp. 185-206). Springer, Dordrecht.	"Serious game as a term is not clearly defined, and many games labelled under it can easily be categorised to other genres as well".
2010	de Heer. *Serious Gaming is Serious Business in Urban Planning*	"In our view, a serious game provides the means to an end regarding simplifying reality and allowing for human interaction. The goal of a serious game system is to reduce complexity to such a level of abstraction that the players can easily interact with it and discuss it with each other, without losing the link or transfer to reality while stimulating the players to stay focused and busy. Further, in the context of the urban planning challenge our game system supports the development of a joint final solution thereby giving the players the opportunity in accomplishing their own interests, while they are encouraged to work together to achieve a common goal."
2011	Bronack, S.C. (2011). The Role of Immersive Media in Online Education. The Journal of Continuing Higher Education, 59, (pp. 113–117).	Serious games are one of the fastest-growing areas in immersive educational media today
2012	Mouaheb H. et al. *The serious game: what educational benefits?* Procedia-Social and Behavioral Sciences, 46, 5502-5508.	"Given the diversity of its applications, it appears that the concept of "Serious Game" is a vast field that is not limited to training and may, in particular, be used for other educational purposes."

2.2.1 Areas of application

The evolution towards taking serious games "seriously" has not been a linear process but rather an eventful one dictated by constant turnovers (Wilkinson, 2016). According to the work of Juul (2001) and Avedon and Smith (2015), there is a historical oscillation regarding the significance and the application fields of serious games. Current scholars consider serious games interdisciplinary but there are

dominant disciplines in which they are mostly used (Wilkinson, 2016). When they were initially employed, serious games had been originally created to train people for specific professional skills, such as military training, or insurance salesmen training. These types of skills were all characterized by their specificity and applicability in particular work-related purposes and intended for an exclusive audience (Bellotti, Berta and De Gloria, 2010b). Moreover, some other experiences show serious games applied in business and management. Further uses of serious games concern politics and medical professions (Susi, Johannesson and Backlund, 2007). For what concerns medical serious games, professionals and patients will be involved to develop medical knowledge and skills. Such games may be available and collected for instance in "Game for Health"[6]. The current trends show that the research of serious games is mostly focused upon social sciences, psychology and of course, computer science (Wilkinson, 2016). In such regards, Klopfer, Osterweil, and Salen (2009), stated that the use of serious games ranges from social issues to promote human wellbeing and healthy lifestyle. The games created for social or political issues are mainly grouped in Games for Change[7]. Further proof of serious games' adaptability is found in the literature, which shows how serious games can be applied to a wide range of disciplines and are classified according to the field they engage with. Serious games may be categorised between: pedagogical, idealistic, politic, societal, educational, healthcare, national security, corporate management[8], and more, or education, health, public policy, science, government, and corporate training[9] (Susi, Johannesson and Backlund, 2007).Although serious games can be used in such a variety of contexts, they have all share the ultimate aim to motivate, educate, involve and raise awareness, all communicated through (Pannese and Carlesi, 2007; Bellotti et al., 2009; Aylett et al., 2009; Qin et al., 2010; Petrasova et al., 2010). In fact, according to the scientific community, there is a large consensus on the potential of games, mostly as they are such motivational and engaging tools (Mitchell and Savall-Smith, 2004; Kirriemuir and McFarlane, 2004; Iacovides, 2009). In actual fact serious games are often designed as virtual environments explicitly intended to educate or train players.

Among those application fields, serious games have become increasingly popular as an educational tool in academic settings such as schools and universities (Katsaliaki and Mustafee, 2012).

Due to the unique features of serious games through other tools, it is possible to teach and educate students by providing leisure, making the learning experience more enjoyable and motivating. According to the research of Hirose, Sugiura, and

[6] gamesfor.health/
[7] gamesforchange.org/
[8] coventry.ac.uk
[9] usatoday.com

Shimomoto (2004) and Philpot et al. (2005) the simulation induced by serious games helps students increase their awareness of real-world issues and improve their understanding of course topics. This further proves how, serious games tackling sustainable development issues can be an effective teaching and training tool to all the stakeholders directly affected by the phenomenon (Katsaliaki and Mustafee, 2012). In this respect, applying serious games can actively involve those who work to provide solutions to sustainability challenges, such as governments, academics, organisations, students and professionals.

The game *MyGreenPlanet*, tackles the issues just described by: "creating awareness and promoting attitudinal and behavioural changes on sustainable issues is crucial, and serious games can play an important role by allowing players to experience unfamiliar circumstances that are not possible in real life: for instance, being a mayor with the power to change a whole city towards a more sustainable place, balancing pollution, energetic productivity and citizens' happiness as players experienced" (Ouariachi, Elving, and Pierie 2018).

Other kinds of serious games which may differ in type, mode and genre can also deal with sustainability issues. For instance, the card game *Keep Cool*, analyses sustainability through another method: players represent groups of countries that negotiate economic growth and climate change mitigation. Or also, another example may be *Climate Mission 3D*, a mobile game in which players learn how to reduce their carbon footprint by playing a series of mini-games. *Energy 2020* entails another typology, whereby the players' task is to reduce energy consumption by increasing energy efficiency and choosing the best renewable energies. In this game, economic, environmental and social indicators help players take reasonable decisions to improve the collective future. All games related to sustainability issues have particular and distinct storylines. However, many of them often portray the role of a citizen or mayor or local administrator, who makes daily-life decisions regarding sustainability, such as energy and water saving, recycling, buying ecological food, etc. These are just a few examples of serious games tackling sustainability, looking into specific matters such as energy efficiency, climate change, economic growth, social and environmental impact of human actions. Nevertheless, these cases show that serious games aim to provide basic knowledge on environmental issues to raise awareness of its causes and consequences and to promote a positive change in the approach and behaviour.

One of the research activities carried out in this thesis is therefore the identification of serious games relevant to sustainable development and sustainability issues. This research has been conducted by studying two sources: the scholarly literature, and an online game on sustainability, accessible on the internet. The results of this research, summarised in Chapter 4, can be interpreted as a new classification of

serious games that I have attained by considering games developed from 2007 to 2018.
From the results retrieved through this new classification, it was found that many themes in the games are closely linked to sustainable development issues. This has made it possible to achieve the purpose of the classification, namely to recognise and identify the SDGs to which the games refer. These types of serious games are therefore able to transmit knowledge on sustainability, to stimulate the development of alternative ideas that support problem solving.
As the literature supports the ability of serious games to impart knowledge about sustainability (Von Wangenheim and Shull, 2009; Liarakau et al., 2012; Katsaliaki and Mustafee, 2014; Petri and Von Wangenheim, 2016; Emblen-Perry, 2018), this research thoroughly explored the educational role in these games.

2.3 Serious games and learning

Serious games are used as particular approaches that aim to solve complex issues. Their application covers all the aspects of education such as teaching, training and informing and, thanks to this versatility, they can be applied in different pedagogic contexts. Using serious games as educational learning tools provides some advantages, including the possibility to experience situations that are impossible to obtain in real life, in terms of cost, safety, time, etc... (Corti, 2006; Squire, 2002). Furthermore, they allow people to be engaged in an instructional journey, resulting in a constructive impact on the player's development of several skills. The latter entail analytical and spatial skills, strategic skills, visual attention, and learning and recollection capabilities (Mitchell and Savill-Smith, 2004). Regarding learning capabilities, different scholars identified numerous reasons why games can be considered educational tools. These include the studies of Malone and Lepper (1987) about the intrinsic motivation enhanced in games, the experiential learning taking place while playing (Dieleman and Huisingh, 2006), the presence of educational values in game design stated by Becker (2007), and finally the access to shared social practices for the establishment of knowledge (Gee 2007; Steinkuehler 2008). Furthermore, Michael and Chen (2005) stated "serious games like every other tool of education must be able to show that the necessary learning has occurred". For serious games to be considered a valid teaching tool, they must provide some form of testing and progress monitoring. Moreover, the tests must be consisted with the context of the education or training they are attempting to provide. Learning is a complex process, which is really difficult to measure. Consequently, determining whether a serious game is effective in achieving the intended learning objectives is also a challenging, time-consuming, expensive and difficult task (Hays, 2005; Enfield et al., 2012; Bellotti et al., 2013).

2.3.1 Learning by playing

Most of the studies use a simple research design in evaluation contexts (one-shot post-test only): typically, after the game is used, subjective information is collected via non-standardized questionnaires, or through informal interviews with the learners (Von Wangenheim and Shull, 2009).
Very few studies employ a (quasi-)experimental design for evaluation (Pfahl et al., 2003; Vogel et al., 2006; Navarro and Hoek, 2007; Von Wangenheim et al., 2008).
In terms of evaluation purpose, most studies represent explorative research focusing on learning effectiveness and enjoyability, as well as the identification of strengths and weaknesses of the game. The difficulty of measuring a game's learning effectiveness is widely recognized in the education community, the majority of the studies do not adopt evaluation practices from the education community, nor do they discuss potential threats to validity.

Transformative learning

Bateson's concept of learning levels (1972) is divided into 3 different moments: In, Through and Beyond.

- IN

Defined also as the "Learning zero": it is a linear process, the first and most basic level of approach. Here, players of serious games collect inputs, data and information and react to it with no particular justifiable reason.

- THROUGH

Generally known as "Learning one": it is contextual learning, a choice between several alternatives in specific contexts, a process of change and repetition. Through the game, the players learn how to use different strategies, concepts and patterns to succeed in the game.

- BEYOND

This level is also defined as the "Deuntero-learning": in which the learning level is expanded to real-life contexts and the game fosters a transformation of the player's self and worldview. This form of learning is defined as transformative learning (Merizow, 1996; Buck, 1989; Mitgutsch, 2009). If serious games are designed to change the player's perspective on something, they aim towards serious and transformative learning processes. Although most researches study the transferal of behaviour, knowledge, literacies and skills, little is known about deep and meaningful transformative learning processes achieved through playing serious games. Educational games (or serious games) are specifically designed to teach people about a certain subject, expand on concepts, reinforce development, or assist them when learning a skill or seeking a change of attitude as they play (Dempsey, Lucassen, & Rasmussen, 1996). Prieto (2005) stated that learning tools, such as educational games, need to be developed within the context of the instructional environment in which they are applied, clearly defining their learning objectives in alignment with the learning goals of the instructional unit and be systematically evaluated. Instructional design approaches describe the analysis of learning needs and goals, the development of materials, activities, tests and the evaluation of instructional design (Filatro, 2008). One of the best-known models of instructional design is ADDIE - Analyze, Design, Develop, Implement and Evaluate (Molenda,

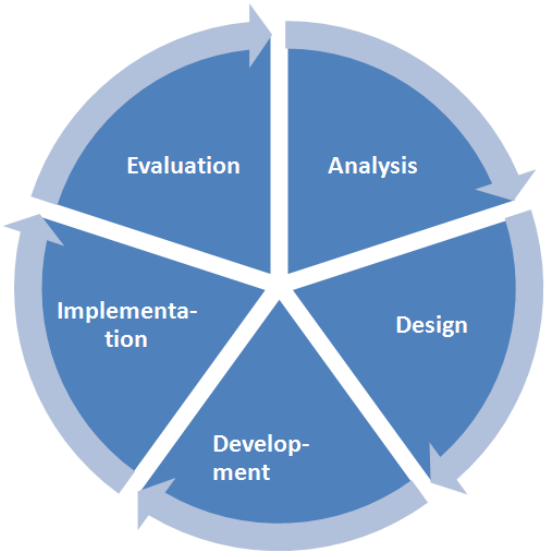

Figure 9_ Basic steps of ADDIE (Molenda, 2003)

2003). As shown in *Figure 9*, ADDIE guides the process of developing learning objects, starting from the analysis of educational needs and the definition of the learning goals of the instructional unit. Initially, in the design phase, both the instructional strategy and its materials are conceived. In the following development phase, the materials are created. Subsequently, implementation occurs as instructors are trained and the learning object is applied. Finally in the assessment phase, the

learning object is assessed and feedback is collected to improve it. In this context, evaluation is an essential step in instructional design, given the need to assess whether each Learning Object (LO) accomplishes what it intends (Montilva, Barrios, & Sandia, 2002; Padrón, Díaz, & Aedo, 2007). This is crucial as normally, even experienced instructional designers do not develop perfect LOs, and when applied, they may not work as intended (Morrison, Ross, & Kemp, 2003; Romiszowski, 2004). The assessment objectives tend to focus on qualities of the LO itself (such as completeness, correctness, consistency, etc.) and/or effects on students, evaluating, for example, the degree of learning achieved, motivation, etc. (Filatro, 2008). Specifically, the success of LOs can be assessed on different levels following Kirkpatrick's Four Levels of Evaluation (Kirkpatrick & Kirkpatrick, 2006), as shown in *Figure 8*, a popular model for the evaluation of training programs and learning effects. Through the evaluation objective and level, they can be conducted using different research designs varying from informal studies, case studies to formal experiments (Kirkpatrick and Kirkpatrick, 2006).

Table 8_ Overview on Kirkpatrick's four-level model for evaluation (Kirkpatrick and Kirkpatrick, 2006)

Evaluation level	Description	Examples of evaluation tools and methods
1. Reaction	Evaluates how the students felt about the training or learning experience.	Happy-sheets; feedback forms; verbal reactions; post-training surveys; ...
2. Learning	Evaluates the increase in knowledge or capability (before and after)	Assessments and tests before and after the training; interviews or observation
3. Behaviour	Evaluates the extent of applied learning back on the job implementation.	Observation and interviews over time to assess change, relevance of change and sustainability of change.
4. Results	Evaluation of the effect on the business or environment by the trainee.	Long-term post-training surveys; observation as part of ongoing, sequenced training and coaching over a while; measures, such as, rework, errors, etc. to measure, if participants achieved training objectives; interviews with trainees and their managers, or their customer groups.

2.3.1.1 Evaluation of learning by playing

This research aims to identify the state of the art on how to systematically evaluate educational/serious games. To conduct this analysis, the strength of the work of Petri and Von Wangenheim, (2016) was studied.
Petri and Von Wangenheim's 7 approaches:

A. 3 FRAMEWORKS
B. 2 SCALES
C. 1 METHOD
D. 1 MODEL

A. FRAMEWORKS

- de Freitas and Oliver (2006): a framework that evaluates context, learner or learner group, internal world representation/pedagogy used, and learning process. The Four-Dimensional Framework (FDF) is "designed to aid tutors selecting and using games in their practice. The framework includes: context, learner specification, pedagogy used and representation as four key aspects for selecting the correct game for use in learning practice" (de Freitas, 2006). This framework allows practitioners to be more critical about how they embed games and simulations into their lesson plans. It allows researchers and evaluators to develop metrics to support the effective analysis of existing educational games and simulations and allows educational designers to consider a more user-based and specialized set of educationally specific factors. The four dimensions evaluated by the framework are reported in *Figure 10* and they are: pedagogic considerations, learner or learner specification, context and mode of representation (Petri and Von Wangenheim, 2016). Pedagogic considerations refer to learning models used, approaches taken etc. Learner specification clarify and better define the characteristics of learners through learner profile, pathways, learning background, group profile etc. Contexts are the places where learning happens and they can be classroom-based, outdoors, access to equipment, technical support, etc. Finally, the mode of representation stands for level of fidelity, interactivity, immersion etc.

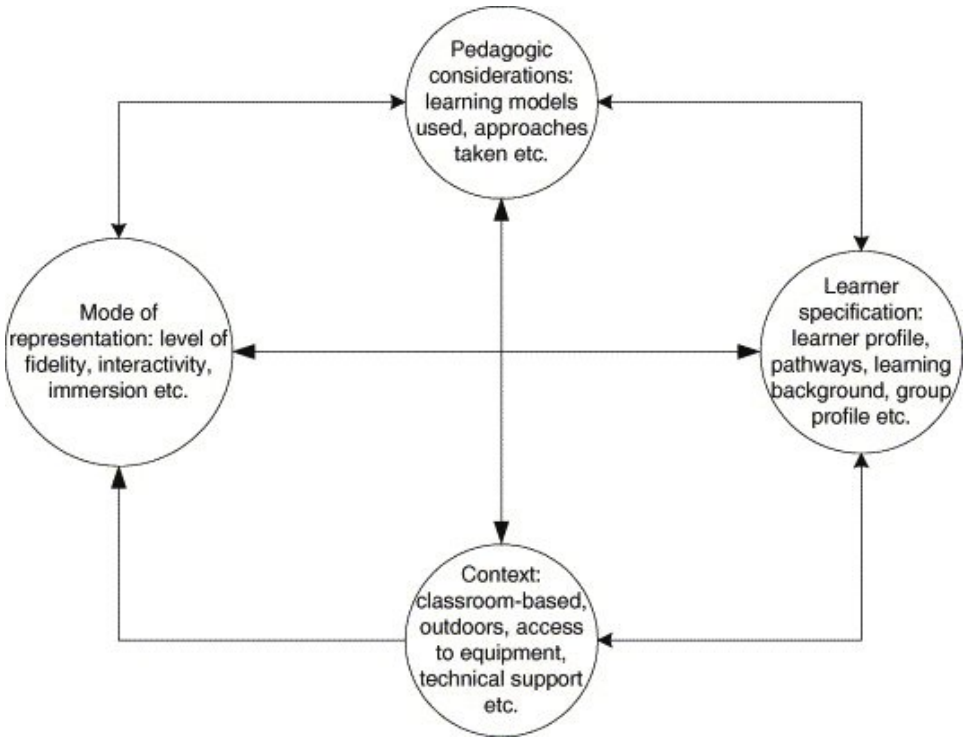

Figure 10_The Four-Dimensional Framework (de Freitas & Oliver 2006)

- Connolly, Stansfield and Hainey (2009): evaluation framework for effective GBL concerning 7 dimensions. The main objective of this framework is to identify what can be evaluated in a GBL application. As shown in *Figure 11*, such applications can be evaluated in terms of learner performance, learner/academic motivation, learner/academic perceptions, learner/academic preferences, the GBL environment itself and the collaboration between players (Connolly, Stansfield and Hainey, 2009). The framework can be customized to particular requirements depending on the needed particular analytical measurements (Petri and Von Wangenheim, 2016). Such a framework can be used both in a "developmental sense to inform design during the implementation and embedding of a GBL application in curricula in a formative assessment sense and also, points to examples of individual analytical measures, already in the literature, to focus on assessment at the end of development in a summative assessment sense" (Connolly, Stansfield and Hainey, 2009).

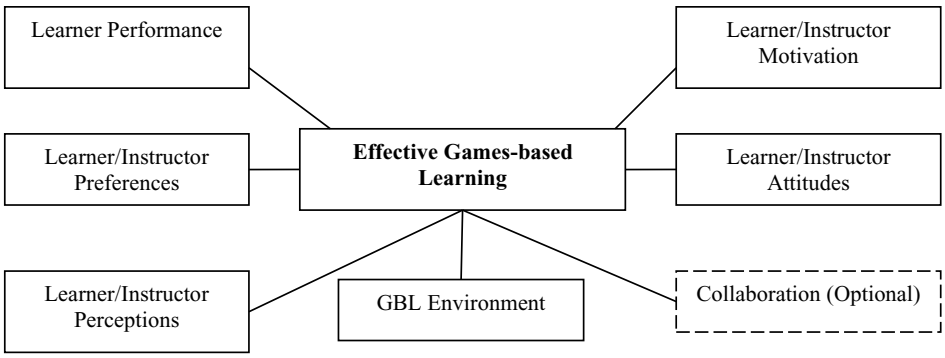

Figure 11_ Evaluation Framework for Effective Games-based Learning (Connolly, Stansfield and Haine 2009).

- Carvalho (2012): evaluation framework that assesses the efficiency of GBL focusing on engineering education.
  Covering the two first levels of Kirkpatrick's evaluation model, reaction and learning, (Kirkpatrick, 2006), the framework is structured into three stages: alpha-testing, beta-testing and gamma-testing each with clear objectives, predefined protocols and data collection tools. The framework assesses the games' efficiency in terms of gameplay, game-story, mechanisms, usability, knowledge, motivation, and satisfaction (Petri and Von Wangenheim, 2016);

B. SCALES

- Fu, Su and Yu (2009): presents EGameFlow, a scale that assesses user satisfaction of learning games to help developers understand strengths and weaknesses from the students' perception in accordance to evaluation level 1 (reaction) (Kirkpatrick, 2006). It estimates the game's quality through the following eight factors: concentration, goal clarity, feedback, challenge, autonomy, immersion, social interaction and knowledge improvement (Petri and Von Wangenheim, 2016);
- Ak (2012): This scale aims to select good educational computer games, attempting to measure their quality before applying them in class. Game quality is measured in terms of enjoyment and learning. (Petri and Von Wangenheim, 2016);

C. METHOD

- Mayer (2012): assesses in 3 moments, pre-game, in-game and post-game. This generic evaluation methodology for serious gaming consists of

frameworks, conceptual models, research designs, evaluation constructs and scales, and data collection techniques. Such methodology estimates serious games in three moments (pre-game, in-game, and post-game) in terms of previous experiences/skills, game performance, gameplay, game experience, player satisfaction, and learning (Petri and Von Wangenheim, 2016);

D. MODEL

- Savi, Von Wangenheim and Borgatto (2011): MEEGA (Model for the Evaluation of Educational Games) is specifically developed for the assessment of educational games. The model focuses on evaluation level 1-reaction (Kirkpatrick, 2006), capturing the reaction of students after they have played the game, by applying a standardized questionnaire. MEEGA measures three quality dimensions of educational games: motivation, user experience, and learning. In addition, the model is accompanied by a process on how to apply the evaluation model in practice (Petri and Von Wangenheim, 2016).

The two most comprehensive supports have been identified in the Mayer and in the MEEGA system. Mayer (2012) proposes a generic evaluation method for serious games. Nonetheless, although the method provides comprehensive support, which includes a framework, conceptual models, research designs, evaluation constructs and scales, and data gathering techniques, no information on the applicability and validity of this method have been determined. On the other hand, the MEEGA (Savi, Von Wangenheim and Borgatto, 2011) provides an evaluation method through the evaluation process based on the MEEGA model that has been systematically developed through the Goal Question Metric-GQM approach (Basili et al, 1994) to explicitly define a measurement program. This model has been evaluated in terms of its applicability, usefulness, validity and reliability through a series of case studies. Currently, MEEGA seems to be used more widely in practice, as reported by several studies evaluating different games and contexts researched by various authors (Calderón, 2015).

As mentioned before, the subcomponent motivation is deconstructed based on the ARCS model (Keller, 1983), which defines four categories to represent motivation in instructional design: *attention, relevance, confidence and satisfaction*. The first (*attention*) refers to students' cognitive responses to instructional stimuli. It is desirable to obtain and maintain a satisfactory level of attention of students during a learning period. Following, *relevance* refers to the students' need to realize that the educational proposal is consistent with their goals and that they can link content with their professional or in their academic future. *Confidence* aims to enable the

students to make progress in the study of educational content through their effort and ability (e.g., through exercises with increasing level of difficulty). Lastly, *satisfaction* requires that the students must realise their results from their learning efforts. The subcomponent user experience (UX) covers the interaction of individuals with the game, considering thoughts, feelings, amusement and other perceptions that result from the interaction (Tullis and Albert, 2008).

The user experience (Norman, 1995) is the experience that people have when interacting with a product in the real world. It can make the difference between a successful product and a complete failure. UX is neither the graphical appearance of a product nor the totality of its functionality's contacts with the product. According to Nielsen and Norman, User Experience encompasses all aspects of end-user interaction with the product. From imagining its use to remembering its effects, passing through the phase of actual interaction. As Garrett points out (2010), all objects/services used by people have their own UX. The user experience can be both positive and negative. If a product does not work as people expect, they will feel frustrated, and even if they manage to finish the task, they set themselves. The design process of the UX must ensure that all aspects are the result of a specific intent of the designer.

According to Garrett (2011), the process of UX design of a software product can be deconstructed into 5 steps that correspond to 5 reading plans: surface, skeleton, structure, scope and strategy. Strategy analyses users' needs and the goals that clients want to achieve. Scope involves all the product's functionalities while the structure defines the organisation of the logical structure of the product, through the various paths that the user can follow. The skeleton is the scheme of the product that defines the position of interface elements (buttons, controls, images, text blocks). Finally, surface involves what the user sees and can interact with, such as a series of screens made up of text and images. Such 5 plans provide a conceptual framework that allows researchers to analyse user experience problems and to find the tools to be used to solve them.

In particular about games, UX is usually measured by a set of dimensions, yet, "there does not exist" a consensus on which ones. Synthesizing prominent models of UX in games (Sweetser and Wyeth, 2005; Poels, Kort, and Ijsselsteijn, 2007; Gámez, 2009; Takatalo et al., 2010, Savi, Von Wangenheim and Borgatto, 2011) propose the following common dimensions: *immersion, challenge, competence, amusement, social interaction and control*. The first, *immersion* refers to the feature that allows the player to have an experience of deep involvement within the game, creating a challenge with real-world focus, so to create a total detachment from the outside world during gameplay. *Social interaction* refers to the creation of a feeling of a shared environment and connection to others in activities of cooperation or competition. Further, *challenge* entails that a game requires a certain level of

challenging stimulation concerning the players' competency level. The increase of difficulty should maintain an appropriate pace accompanying the learning curve of the students. New obstacles, situations and changes in activities should be planned throughout the game to minimize fatigue and to keep the students interested. Games should also provide entertainment, enjoyment, amusement, recreation, leisure and satisfaction.

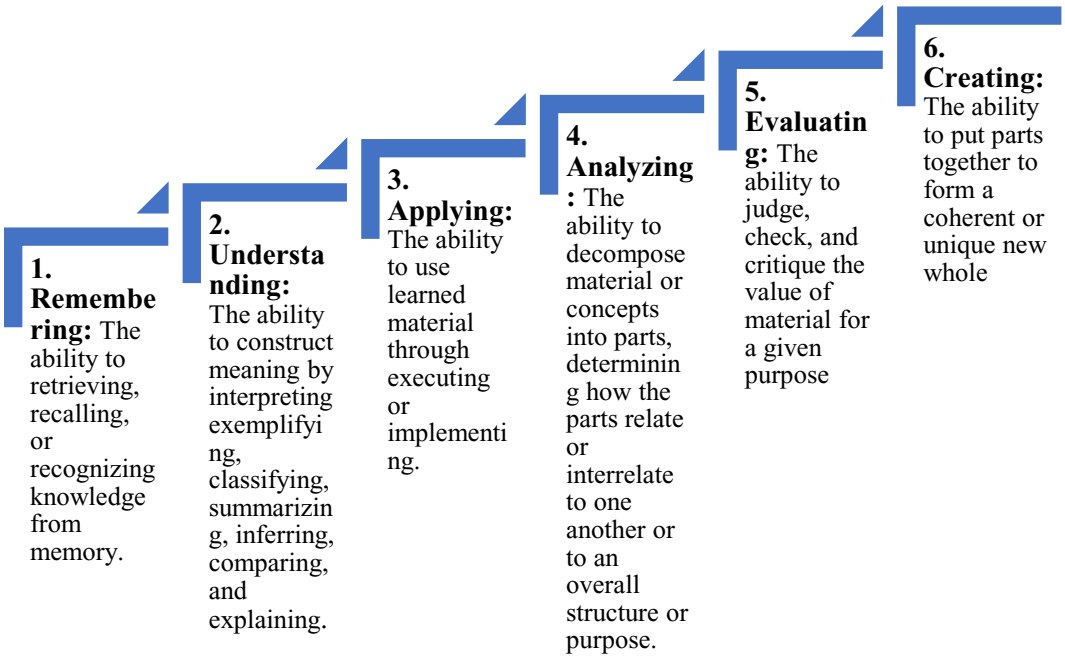

Figure 12_ Revised version of Bloom's taxonomy of educational objectives according to Petri and von Wangenheim (2016)

The evaluation of short-term learning is based on the more immediate educational goals, activities or instructional materials of a course. In contrast, long-term learning focuses on the analysis of whether the instructional units contribute to the professional life of the individual. In this way, learners could give the high ratings on the learning, even perhaps without actually learning and achieving anything.
Learners have a reputation for being overly optimistic about their ability to remember information. Yet, in literature, the question of reliability and validity of learner's self-assessments is controversial. Although it seems to be a reliable assessment technique, evidence of the validity of self-assessment is controversial (Ross, 2006). But even though there is no consensus, there is proof that self-assessment provides reliable, valid and useful information (Topping, 2003; Ross,

2006). Considering the accuracy of student's self-assessment compared with the scores assigned by teachers, it is worth mentioning that there are studies that indicate a moderate level of correlation between self-assessment of students with test scores corrected by teachers (Falchikov and Boud, 1989; Seymour et al., 2000; Sindre and Moody, 2003). Besides, since teacher assessments and or evaluations are made in a pre/post-test design, they may lack legitimacy as studies demonstrate that different assessments that teachers appoint to the student's same work may also vary considerably (Falchikov and Boud, 1989; Topping, 2003). Or warnings may be introduced through variations between pre/post-tests and/or the influence of additional causal factors on the test results not being controlled. To summarize, a major concern is that self-assessments of students may indicate a higher indication of the learning process than that which has actually occurred, which may be inferior than that indicated in the review (Ross, Rolheiser, and Hogaboam-Gray, 1998). However, when assessing the quality of a game, there are fewer reasons for students seeking to take advantage of this assessment. From this discussion, it becomes clear that assessing the learning effect is a complex issue (Petri and Von Wangenheim, 2016). To evaluate the effect of a game from the student's perception, an alternative is proposed here, with the advantage of maintaining the application of the model simple and quick, without requiring advanced knowledge, but still offering a reasonable trend on the effect of the game. Petri and Von Wangenheim (2016) developed a questionnaire following DeVellis' (2003) method to define measurement scales. The questionnaire has been developed based on the defined theoretical evaluation model customizing and unifying existing standardized questionnaires (Keller, 1983; Tullis & Albert, 2008; Sindre & Moody, 2003; Sweetser and Wyeth, 2005; Poels et al., 2007; Gámez, 2009; Takatalo et al., 2010).

Item no.	Dimension	Item
Sub-component Motivation		
1	Attention	The game design is attractive.
2	Attention	There was something interesting at the beginning of the game that captured my attention
3	Attention	The variation (form, content or activities) helped me to keep attention to the game
4	Relevance	The game content is relevant to my interests.
5	Relevance	The way the game works suits my way of learning.
6	Relevance	The game content is connected to other knowledge I already had
7	Confidence	It was easy to understand the game and start using it as study material
8	Confidence	Passing through the game, I felt confident that I was learning
9	Satisfaction	I am satisfied because I know I will have opportunities to use in practice things I learned playing this game
10	Satisfaction	It is due to my personal effort that I manage to advance in the game.

Sub-component User Experien		
11	Immersion	Temporarily I forgot about my daily; I have been fully concentrated on the game
12	Immersion	I did not notice the time pass while playing; when I saw the game had already ended
13	Immersion	I felt myself more in the game context than real life, forgetting what was around me
14	Social Interaction	I was able to interact with others during the game.
15	Social Interaction	I had fun with other people
16	Social Interaction	The game promotes moments of cooperation and/ or competition between the players
17	Challenge	This game is appropriately challenging for me, the tasks are not too easy nor too difficult
18	Challenge	The game progresses at an adequate pace and does not become monotonous - offers new obstacles, situations or variations in its tasks.
19	Fun	I had fun with the game
20	Fun	When interrupted at the end of the class, I was disappointed that the game was over
21	Fun	I would recommend this game to my colleagues.
22	Competence	I achieved the goals of the game applying my knowledge.
23	Competence	I had positive feelings on the efficiency of this game.
24	Fun	I would like to play this game again.
Sub-component Learning		
25	Short-term learning	How much do you think the game contributed to your learning about sustainability?
26	Short-term learning	How efficient was the game for your learning, comparing it with other activities of the courses?
27	Long-term learning	Do you think the experience with the game will contribute to your professional performance in practise?

The MEEGA model (**Errore. L'origine riferimento non è stata trovata.**) has been applied and trailed through a series of case studies within two different contexts on four different games. The first results indicate that the model is easy to apply in a non-intrusive way and provides useful feedback for game creators and/or instructors. Based on the assessment results, the authors consider the proposed model acceptable in terms of validity and reliability, although, they identified a lack of intercorrelation between items of two subscales (motivation and user experience). In this respect, the proposed model provides a simple opportunity for game creators or instructors to evaluate the impact of such games in their classrooms.

2.3.2 Learning by making

Playing serious games has proven to be a valuable and effective approach for ESD. However, in the last decade, a new trend is emerging, emphasising the design and

development of games as a learning activity. Therefore, instead of transferring the educational content through gameplay, users are spurred to learn by designing the games on a specific theme (Kafai 2006). This approach lays its foundation on constructionist theory in the context of game making (Papert and Harel 1991). By constructing a physical artefact (i.e., a game), the learner must build representations of the world according to their understanding (Kafai 1998). Thus, by designing and developing the rules and interactions upon which a game is built, users establish a link between the physical artefact and their mental representation of a specific topic, eventually creating a new personal relationship with knowledge. Overall, this methodology can better motivate students resulting in more meaningful learning outcomes (Bruckman and Resnick 1995; Baytak and Land 2011). Moreover, constructionism stresses the importance of the social context in which game-making takes place. Through dialogue, interaction and confrontation with peers, students collectively think, reflect and share knowledge. Thus, by fostering group dynamics, a favourable setting for learning is established. However, these benefits arise not only from the aftermath of the game-making process. In fact, they are also the product of the community of players who will play the game (Kafai and Burke 2015). Through feedback and interchange that can occur between the creators and the players, further learning and elaboration opportunities can be initiated. Nevertheless, creating a game for peers to play, increases students' motivation towards the development phase and indirectly, the learning process. As highlighted by many experts (Kafai and Burke 2015; Jeffrey Earp 2015), creating learning games has primarily targeted K12 students in out-of-school activities, such as summer camps and after-school clubs whereas fewer examples can be found in higher education. Across all educational levels, the main objective for learning through game making has been teaching programming skills (Al-Makhzoomy, Zhang, and Spannaus 2020; Basawapatna, Koh, and Repenning 2010; Eow et al. 2010; Denner, Werner, and Ortiz 2012). This broad approach has been mainly driven by the tight connection between programming and digital game creation (i.e., programming is a founding tool). Thus, students are more motivated to learn these skills by directly applying them to create a meaningful artefact (i.e., the game). In these examples, the focus is not on the game's subject, but rather on the process of creating it. Nonetheless, recent research is also exploring serious games making to transfer knowledge regarding the specific topic addressed by the game. In this regard, STEM[10] subjects are the most employed. Specifically, students have been prompted to learn math (Garneli et al. 2013; Ke 2014), chemical engineering (Fornós 2020), or data literacy (Werning 2020). Although the taught disciplines may differ, most authors could not find quantitative data demonstrating learning outcomes on the specific subjects the interventions

[10] Science, Technology, Engineering and Mathematics

regarded. This is mainly due to the (i) length of the activities which were probably too short (i.e., ranging from 1 week to 1 month) and (ii) the difficulty of evaluating learning effects. Nevertheless, from the qualitative assessment of the studies, carried through interviews, questionnaires or video recording analysis, researchers were able to observe that learning through game making supported the development of 21st century skills, such as creativity, innovation, communication, collaboration, critical thinking, and problem-solving. Finally, the majority of the involved students expressed a positive interest in repeating a similar activity. Therefore, results are promising, but, according to all authors, more research is required in this unexploited learning paradigm.

One of the most interesting novelties of this work is the enlarged target audience, which usually comprises of K12[11] students. Here, HE (higher education) students are asked to develop serious games, targeting sustainability-related themes, which they would then play. Most of the time, authors' findings are promising and aligned with previous works: (i) students' engagement and appreciation are high and (ii) learning outcomes are difficult to assess. In this case, the main limitations underlined by authors have been the limited time given to students to design and develop the games.

2.3.2.1 Potential benefits

In the traditional form of education systems, oral and written exams are considered the primary assessment methods to analyse students' results. The data of these evaluations is restricted to students and educators and generally, it is disclosed until the activities are completed or it is too late to intervene (Arnab et al., 2015). Since it is interesting to analyse the power of this data, the learning processes and experience can be broken down into measurable steps, to assess intermediate knowledge transfer. Until now, the available set of parameters to analyse educational outcomes has not been enough to establish the conditions of success or failure in the different educational processes (Arnab et al., 2015; Davenport, 2008).

The increasing acceptance of serious games leads teachers from different areas and levels to use games to engage their students. However, most of these activities do not have an important weight on the final students' evaluation, because most games and simulations lack an appropriate assessment system able to generate rigorous and reliable feedback on student results (Arnab et al., 2015). Although the goal of serious games is to teach through innovative ways, a valuable evaluation system of their effectiveness is unfortunately missing, as they are generally evaluated through

[11]K12 is a short form for the publicly-supported school grades prior to college. These grades are kindergarten (K) and the 1st through the 12th grade (1-12).

written examination or debriefing sessions (Arnab et al., 2013; Peters and Vissers, 2008).

This has caused an increasing gap between the purportedly deep learning that can be conveyed through serious games and the insubstantial techniques used to assess learners' performance. This is why it is important to bring together serious games and learning analytics. Through this strong collaborative method, it is possible to facilitate understanding and to support the engagement of learners by opening the possibility to create an intelligent and interoperable learning framework (*Figure 13*). This aims to support the achievement of large-scale educational data by engaging sources to better understand learners' knowledge, assess their progress and provide feedback, that is crucial for the stakeholders involved, both students and teachers (Arnab et al., 2015). Moreover, according to them, the potential benefits for the participants in the conceptual learning system are classified in four levels:

- Course-Level in which learners and teachers/professors achieve a better perspective of the educational process and relating results. In this case, the learners can reach their goals and the teachers/professors can provide the right support to their trainees. For instance, learners receive active feedback from specific courses that allow teachers to optimize solutions and face interventions related to the insights provided at the courses;
- Course-Aggregated Level where the learning strategy is enriched through actionable solutions to overcome the weakness. The models and success/failure schemes can be related to specific data of measurements and metrics;
- Administration-Level occurs when it is possible to gain more detailed statics of a group of students to improve resources allocation, instructional or change strategy;
- Regional/State Level is related to specific studies carried out from many schools or faculties that can be compared to study how education strategy and policy have been developed at national or regional level. Among the analyses, it is particularly crucial to focus on practical support of

geographical and cultural contexts, to understand teacher's and students' expectations of digital resources.

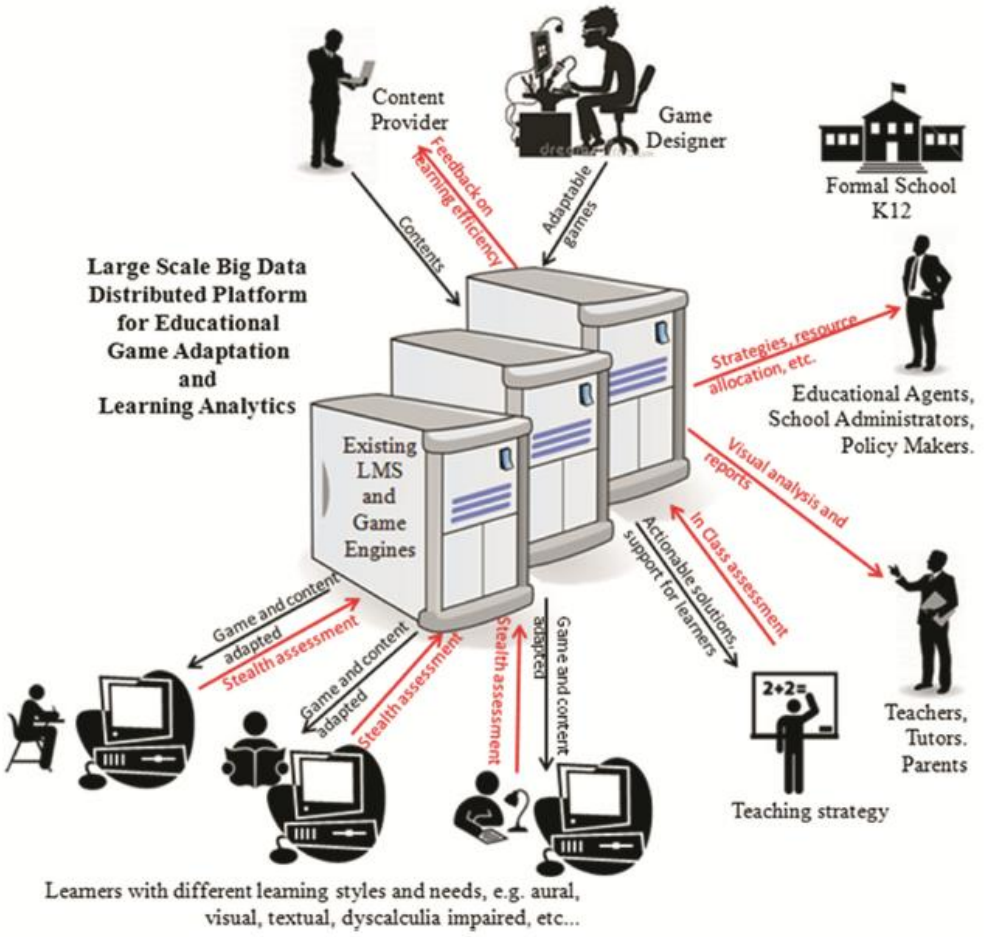

Figure 13_ A conceptual system of data distribution for educational/serious games and learning analytics (Arnab et al., 2015)

The Talenti Polito Challenge is an experiment to test the potential benefits of serious game learning according to the course-level. As further development, it will be interesting to expand the analyses until the course-aggregated level. Since the course-level requires solutions and interventions to provide benefits of using serious games, it has started to work on the learning outcomes from designing serious games, instead of simply playing.

Chapter 3

Smart cities and Sustainable Development

Chapter 3 gives an account of the literature review regarding the concepts of smart cities and sustainable development. This chapter explores and elucidates the main definitions and features of smart cities and, subsequently, the role they play in ensuring a sustainable future for the next generations. The pages that follow initiate a discussion on how the concept of smart cities (Hollands, 2008) has received increasing consideration and how it is now conceived as a new response for smart urban development and sustainable socio-economic growth (Neirotti et al., 2014). Smart cities are defined as complex systems encompassing the crossing of different domains such as citizens, businesses, transport systems, communication networks, services and utilities (Neirotti et al., 2014). Such domains are currently damaged by the critically rapid growth that has generated traffic congestion, pollution, and increasing social inequality (Kim and Han, 2012). From this urban crisis, a debate has arisen regarding how new technology-based solutions, as well as new approaches to urban living and planning can ensure a more secure future and fair wealth of city areas and citizens (Alawadhi et al., 2012; Dirks, Keeling, and Dencik, 2009; Nam and Pardo, 2011; Nijaki and Worrel, 2012). In essence, the will to preserve and guarantee a prosperous future for the coming generations, has found a solution in the

concept of sustainable development, reason why it has gained momentum in recent decades.
The following sections outline the stages of research that led to a definition of *sustainable development* shared by the scientific community, up to the establishment of the SDGs in 2015. The aim of these goals, with their 169 targets, is to ensure a sustainable, peaceful, fair and wealthy life for all the inhabitants of our planet today and in the future. The SDGs cover a set of interconnected themes that challenge society, such as health, education, climate action, peace and strong institutions (SDG Compass, 2015). Furthermore, to explore these interconnections, a number of models and tools have been studied in recent years, such as the work of *Joint Research Center* (JRC). Through its mapping of models and tools for the SDGs, the JRC aims to facilitate and improve the use of instruments for sustainability assessments within the SDG framework. Achieving sustainable development requires a good understanding of processes, policy impacts and interconnections (synergies and trade-offs) among the goals. The *KnowSDG* (Knowledge base for the Sustainable Development Goals) [12] *Platform* identifies such interconnections. More precisely, it is an internet platform that provides tools and organises knowledge on policies, indicators, methods and data to support the implementation of the SDGs. It proposes in particular 4 interactive tools including the "Interlinkages" tool, which is built according to the literature based-approach, and is the most suitable to identify the relationships between the goals. The *interlinkages tool* will be extensively examined and it will be selected for the construction of the flowchart, supplying an analysis of the game elements by testing them. Chapter 6 will further discuss and explain the flowchart tests and the use of the *Interlinkages Tool.*

3.1 The context around smart cities

Regardless of the various studies, a shared and official definition of *smart city* is still missing; therefore, in the last 15 years, some authors have attempted to outline its core components and characteristics (*Table 9*). In the literature field, there is a huge number of contributions to the concept of smart cities. This is also due to the fact that many times the adjective "smart" is replaced by "intelligent", "digital", "smarter", "smartness", "sustainable", "cyber", "informational", and "wired" (Hollands, 2008; Cocchia, 2014; de Santis et al., 2014; Albino, Berardi, and Dangelico 2015; Battarra et al., 2016; Husar, Ondrejicka and Varis 2017; Kummitha and Crutzen, 2017; Ferrero et al., 2018). In such regards, Nam and Pardo (2011) focused their studies on the possible meanings of the adjective "smart" in *smart cities*

[12] https://knowsdgs.jrc.ec.europa.eu/

expression. In their studies, they discovered that, in commercial language, "smartness" is especially a more user-friendly term than "intelligent", which generally is contained within "smart". This is because *smartness* is generally achieved when intelligent systems adapt themselves to people's needs.
According to the research conducted by Bibri and Krogstie (2017), the first *smart city* definitions appeared in 1960 with the expression "cybernetically planned cities" and became more common in urban planning around 1980 (Gabrys, 2014), but Dameri and Cocchia (2013) stated that the notion was introduced only in 1994. In the 90s, the concept was related to the use of new ICT towards modern infrastructures inside cities (Albino et al., 2015).
At the beginning of the 2000s, researchers and authors started investigating which aspects are "hidden behind a self-declaratory attribution of the label of the smart city" (Hollands, 2008) in existing smart cities.
Furthermore, Batty et al. (2012) claimed that in recent times the subject of *smart cities* has been fused with *city planning*, incorporating them under the notion of *smart growth*. *Smart growth* is strictly linked to other sustainable constructs, such as energy, land use, communication, transport, and economic development. After the support offered by European Union (EU) to encourage projects entailing smart cities, the number of publications and writings regarding smart cities significantly increased (Jucevicius, Patasiené and Patasius, 2014; Bibri and Krogstie, 2017).
This led to the stipulation of a large number of new definitions provided by the numerous studies, whilst also discovering common issues, such as:

i) the methodologies and taxonomies proposed are focused on specific aspects of smart city (i.e., only on applicable domains or even more stringent, on transportation and mobility), and on a restricted geographic area;

ii) these contributions do not consider a complete vision of smart cities (Ferrero et al., 2018);

iii) several contributions are still too focused on the technical details of *smart city*, neglecting the requirements of stakeholders and management aspects (Crainic, Perboli, and Rosano, 2018). In their work, Albino et al. (2015) describe in an innovative way the main definitions of smart cities given before 2015 (year in which the SDGs were established) by emphasising the on the relevance of ICT technologies instead of human capital. Until then, smart cities had been defined in varying ways, however, it is possible to identify two different lines of research subsumed from the literature review.

The first field of research is technology-centered, focusing on practical domains that are heavily based on the employment of modern ICT in differing contexts: energy consumption, public transport, or waste and water management. From these studies, the relevance that IT and ICT infrastructure have on the definition of these cities emerged. A smart city is generally defined as a place where technologies are applied to connect different types of infrastructures to social, economic, and natural areas (Caragliu et al., 2009; Harrison et al. 2010; Nam and Pardo, 2011). For instance, especially according to corporations such as IBM, Cisco Systems, and Siemens AG, the technological component is key in the notion of smart cities. In an IBM document it was found that the expression "smart city" entails an "instrumented, interconnected and intelligent city" (Harrison et al., 2010). With the use of these 3 adjectives, smart cities are represented as a reality in which ICT infrastructures capture and integrate live real-world data through the use of sensors, meters, personal devices and other similar appliances. This way, it is possible to integrate all the collected data, by allowing communication among various city services to, finally, ensure the inclusion of complex analytics, modelling, optimization and visualization services to create an improved operational decision for cities (Harrison et al., 2010).

This type of approach is subsequently criticized by many authors since it is mostly recognized as the central role of technologies taking into account fewer other factors. IT infrastructures are a key component of smart cities. They must be employed as instruments that connect the clusters characterising smart cities. Human capital/education, social and relational capital together with environmental issues are considered decisive drivers of urban growth (Lombardi et al., 2012). These last described matters comprise of the more people-centered field of research. Even though technology and infrastructure are still influential factors, today research focuses especially on soft domains such as social inclusion, welfare, culture, and human capital (Caragliu, del Bo, and Nijkamp 2011; Toppeta 2010). In other words, cities can be defined as smart when the respective authorities can optimize the exploitation of both tangible and intangible assets, by enhancing the citizens' quality of life, boosting resources' productivity, and tackling emerging issues (Komninos, Pallot, and Schaffers 2013; Schaffers et al. 2011). Moreover, smart cities are an interdisciplinary reality: they require investigation and cooperation across several disciplines, spanning from economics to social sciences, from politics to infrastructure management and others (Celino & Kotoulas, 2013).

The role of people's involvement in urban contexts has risen in the last years. "The ability for all people to communicate with one another and agencies and groups that represent them provides a new sense of possibility to the idea that smart cities are based on smart communities whose citizens can play an active part in their design" (Joshi et al., 2016). There are different ways to involve and take action that allow citizens to participate in decision making of initiatives. In recent years, smart city

planning has become a more and more bottom-up approach, through new forms of collaboration and participatory governance, where the analysis of people's needs and the definition of social objectives drives the selection of specific technologies (Leydesdorff & Deakin, 2011). Such circumstances have encouraged technology to cover an even more relevant and stimulating role. Today, we have imminent access to all sorts of information, directly available just by browsing the internet. Of course, this is not the only way to participate and gain knowledge of smart cities' initiatives. Hence, known methods may be questionnaires, focus and discussion groups, workshops, effective tools for the enhancement of participation and collaboration among people, creating platforms to share opinions and ideas. Debates and comparisons between citizens become more stimulating when they directly communicate with local governance or municipality. As found in the literature (Nalbandian et al., 2013), better results can be achieved when, during moments of confrontation, governance and public bodies participate and collaborate with all citizens. Furthermore, cities can be *smart* also when they include active political participation, citizen services, and good use of the *e-Government* tool for improving the decision-making process, public policymaking and public governance, all at the same time. One of the most significant attributes of smart governance is the ambition to enhance citizen participation both in private and public collaboration. The implementation of smart governance infrastructure can facilitate service integration, collaboration, communication and data exchange. The relationship between public managers and citizens becomes a decisive component towards in defining the role of management in leading smart cities initiatives. In this regard, Corrigan and Joyce (1997) discussed the citizens' right, to be included in the decision-making process of their municipalities: public managers' interaction with the society is essential for the creation of efficient services created for the community. The link between public managers and the community facilitates the partnership among sectors, groups, and individuals (Nalbandian et al., 2013). To further explain, three challenges for public managers can be identified to pinpoint what is administratively sustainable and politically acceptable: "to create and enforce a chain of responsibility that needs to avoid political alignment; to synchronize jurisdiction and other forms of external authority with the problem to be solved; to integrate the real citizen's need in the local government and administrative structures" (Nalbandian et al., 2013). Smart devices, the Internet of Things (IoT), and ICT by far outnumber human beings in smart cities. The rise of IoT applications and the large-scale adoption of web technologies and tools in urban environments have proven that internet-based solutions can successfully address societal challenges (Celino & Kotoulas, 2013). IoT provides the connection between all these objects to facilitate and make people's lives more comfortable and efficient in all situations (Khajenasiria, Estebsarib, Marian, & Gielen, 2016).

Table 9_ Most relevant definitions of smart cities established during the last 20 years

Year	*Author*	*Definition*
2000	Bowerman et al.	A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.
2004	Partridge	"A city where the ICT strengthen the freedom of speech and the accessibility to public information and services"
2007	Giffinger et al.	"A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens." "A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better organize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.".
2008	Hollands	"It is the implementation and deployment of information and communication technology infrastructures to support social and urban growth through improving the economy, citizens' involvement and governmental efficiency."
2009	Caragliu, Del Bo and Nijkamp.	"Safe, secure, environmental and efficient urban centre of the future with advanced infrastructures such as sensors, electronic devices and networks to stimulate sustainable economic growth and a high quality of life."
2009	Eger	A city with a particular idea of the local community, one where city governments,

		enterprises and residents use ICTs to reinvent and reinforce the community's role in the new service economy, create jobs locally and improve the quality of community life.
2010	Harrison et al.	A "smarter" city is "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city…the traditional concept of a physical city infrastructure is extended to a virtual city infrastructure, an integrated framework that will allow cities to gather, integrate, analyze, optimize, and make decisions based on detailed operational data."
2010	Washburn et al.,	"The use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare, public safety, real estate, transportation, and utilities-more intelligent, interconnected, and efficient."
2011	Caragliu et al.	A city has defined smart when "investments in human and social capital and traditional (transportation) and modern (ICT-based) infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government" (p.70).
2011	Nam and Pardo	A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.
2011	Thuzar	People are the protagonists of a smart city, who shape it through continuous interactions. For this reason, other terms have often been associated with the concept of the smart city. For example, creativity is recognized as a key driver of a smart

		city, and thus education, learning, and knowledge have central roles in a smart city.
2011	Winters	A smart city is a center of higher education, for educating people and their skills workforces. Smart cities work as a magnet for creative people by allowing the creation of a "virtuous circle" to improve cities always smarter.
2012	Lombardi et al.	"The application of information and communications technology (ICT) in the context of future cities is often indicated by the notion of smart city… the main focus is not limited to the role of ICT infrastructure but is mainly on the role of human capital/education, social and relational capital, and environmental issues. These are considered important drivers of urban growth."
2012	Kourtit and Nijkamp	Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g., skilled labour force), infrastructural capital (e.g., high-tech communication facilities), social capital (e.g., intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).
2013	Komninos et al.	"Smart cities can be also understood as places generating a particular form of spatial intelligence and innovation, based on sensors, embedded devices, large data sets, and real-time information and response".
2013	Pérez-Martínez et al.	"cities strongly founded on ICT that invest in human and social capital to improve the quality of life of their citizens by fostering economic growth, participatory governance, wise management of resources, sustainability, and efficient mobility, whilst they guarantee the privacy and security of the citizens."
2014	Marsal-Llacuna et al.	Smart Cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more

		efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors
2016	Yigitcanlar	A smart city could be an "ideal form to build the sustainable cities of the 21st century, in the case that a balanced and sustainable view on economic, societal, environmental and institutional development is realised."
2016	Lara et al.	Smart City is a "[...] community that systematically promotes the overall wellbeing for all of its members, and flexible enough to proactively and sustainably become an increasingly better place to live, work and play." (p. 9).
2018	Martin et al.	"A key finding is that the potential to empower and include citizens represent the key to unlocking forms of smart-sustainable urban development that emphasise environmental protection and social equity, rather than merely reinforcing neoliberal forms of urban development." (p. 269).

The reason why there is no official agreement in regards of the definition of "smart cities" is perhaps due to the fact that, overtime, the term has been employed in mainly two distinct "domains" (Albino et al., 2015). On one hand, it has been applied to "hard" domains, which involve buildings, energy grids, natural resources, water management, waste management, mobility, and logistics (Neirotti et al, 2014), where ICT infrastructures play a decisive role in the functioning of the systems. On the other hand, the term has also been applied to "soft domains" such as education, culture, policy innovations, social inclusion, and government, where the use of ICT is not always so determinant (Albino et al., 2015). After the main distinction of smart cities in 2 lines of researches, the literature has elucidated that, potentially they can be represented according to fundamental measures. An organic integration of a city's systems is vital, as Dirks and Keeling stated in 2009. Transportation, buildings, health care, food and water, public safety, energy and education are all essential systems that together create smart cities. The authors agreed with this vision, affirming how no system operates in isolation but, on the contrary, it only functions successfully when operating with the other systems in an integrated view (Albino et al., 2015). Some hypothetical dimensions have been considered to delineate the features of smart cities. Mahizhnan (1999) identified IT education, IT infrastructure,

IT economy and quality of life. According to this, Komninos (2002, 2011) indicated 4 possible dimensions (application technologies, use of technologies for living and working, integrating ICT in infrastructure and bringing ICT and people together to enhance innovation and learning). Subsequently, Giffinger et al. (2007) identified 5 other dimensions of smart cities, respectively: economics, mobility, environment, people and governance. Indeed, this representation was better received by the scientific community: Eger (2009) stated key dimensions of technology, economic development, job growth and increased quality of life. Conjointly, Thuzar (2011) defined smart cities following similar dimensions: quality of life, sustainable economic development, management of natural resources through participatory policies and convergence of economic, social, and environmental goals. In the same year, Nam and Pardo provided another definition of smart cities according to other dimensions, known as economic sociopolitical issues of the city, economic-technical-social issues of the environment, interconnection, instrumentation, integration, applications and innovations. These portrayals of smart cities have shown how, according to their dimensions, even if appointed and defined indifferent terms, the main objectives are always related to people and community, mobility and infrastructure, governance, quality of life and environment. The most commonly used representation to describe the dimensions of smart cities, is comprised of the following 6 components (*Figure 14*): smart economy, smart people, smart governance, smart mobility, smart environment and smart living (Caragliu, del Bo, and Nijkamp 2011; Lombardi et al. 2012; Neirotti et al., 2014; Albino, Berardi, and Dangelico 2015; Bibri and Krogstie, 2017).

The identified clusters of smart cities are described as follows:

- (smart) Economy, related to competition and industry, can be considered one of the major drivers of smart city initiatives. Economic development facilitates the flow of capital, encouraging development in smart cities (Sujata, Saksham, & Tanvi, 2016). Smart cities initiatives are designed to promote IT capacities and establish an agenda for change by industry actions and business development (Cairney, & Speak, 2000).

  The economic outcomes of smart city initiatives are business growth, job creation, workforce development, and productivity improvement.

- (smart) People, related to human capital and educational contexts, include various aspects such as lifelong learning, social and ethnic plurality, creativity and participation in public life (Nam & Pardo, 2011).

  Social capital supports this dimension. The concept of smart city acquires the meaning of a mix of "education/training, culture/arts, and business/commerce with hybrid social, cultural, and economic enterprises" (Winters, 2011). Smart people create and benefit from the social capital of cities. Furthermore, Winters (2011) clarifies how smart cities can be

identified a center of higher education, able to educate individuals and their skills. Such entities can exploit human potential also promoting creative life (Partridge, 2004). In a smart city, the sense of community among citizens comes from the bottom-up approach discussed above. In order to achieve a strong community in smart cities, members and institutions shall work in partnership to transform their environment (Berardi, 2013a, 2013b).
Communities need to feel the desire to take part in urban projects, by participating and promoting urban smart growth.

- (smart) *Governance*, related to participation and e-democracy, has the role of ridding barriers related to language, culture, education and disabilities. This expression entails that different stakeholder are engaged in decision-making and public service. The role of governance, also known as *e-governance,* when using ICT infrastructures, is to bring smart city initiatives to people, keeping the decision-making process transparent. It should work according to citizen-centric and citizen-driven spirit (Albino et al., 2015).
- (smart) *Mobility*, is related to logistics and urban infrastructures, defines how urban planning should operate to provide services and public transport. Through the use of ICT services, urban planning can operate from a global perspective, shifting from individual to collective modes of transport (Letaifa, 2015).
- (smart) *Environment* is related to natural resources, efficiency and sustainability urban issues. Some opportunities can be found in energy management areas by leaders of the cities (Colldahl et al., 2013). The natural environment can be enhanced by certain strategies and the use of ICT infrastructures including solar panels, renewable energy sources and green sustainable solutions.
- (smart) *Living*, related to security and quality of life, is the dimension that promotes social cohesion and safety. According to Toppeta (2010), this dimension is a part of cultural facilities including, social services, e-health and public safety tools such as services networks. Smart sensors and wireless platforms are also widely used tools to develop smart cities. Some systems, such as living labs and incubators are useful centers to increase scholars' interest.

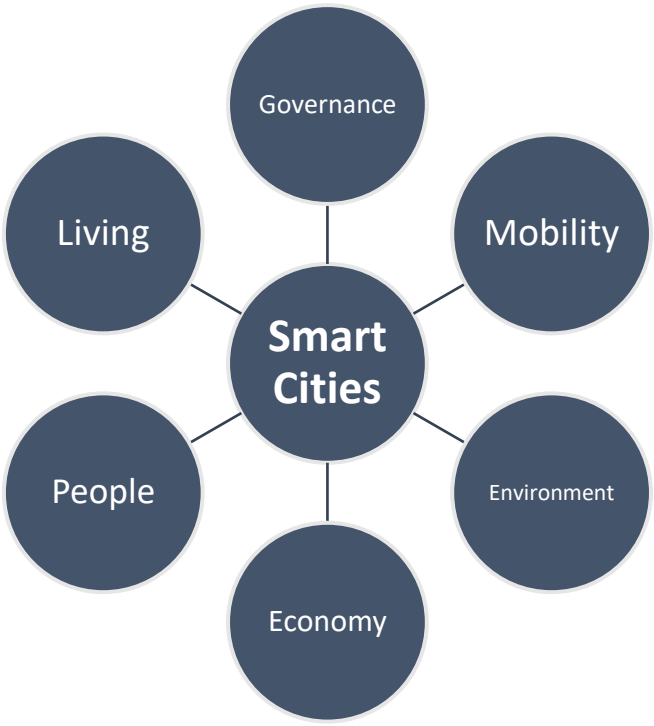

Figure 14_ Representation of the axes of a smart city according to Mattoni, Gugliermetti and Bisegna (2015).

The shared features of the different examples discovered through the analysis of the literature of smart cities are:

- a city's networked infrastructure enabling political efficiency and social and cultural development;
- an emphasis on business-led urban development and creative activities promoting urban growth;
- social inclusion of various urban residents and social capital in urban development investing in the natural environment as a strategic component for the future.

Hence, smart cities are generally composed by the smart clusters previously described: *governance, mobility, environment, economy, people* and *living*. Thus, such cities face a multitude of challenges, including economic limitations, changing demographics, pollution-related issues, traffic congestions which contribute to the advancement of the well-being of cities (Corbett and Mellouli, 2017). As a result, cities across the world have made irregular progress toward sustainability over the past 30 years, fighting to transform vision into reality (Satterthwaite, 1997; Freeman, 2004) and keep the trend of long-term sustainable development on track (Freeman, 2004). The current urban vision has the aim of building a more liveable and attractive urban environment (Al Awadhi and Scholl, 2013). With regard to the environment, smart cities aim to reduce greenhouse gas emissions (Zygiaris, 2013), proficiently control energy through the use of new technologies (Vanolo, 2014) and undertake

other technology-based initiatives to support the sustainable development of their communities. In the next section, the topic of sustainable development will be thoroughly discussed.

3.2 Sustainable Development

From the 1960s onwards, the environmental impact of economies began to be addressed and discussed, as Silent Spring (Carson, 1962) and the Club of Rome report (Meadows et al., 1972) show. The concept of sustainability has taken over as an element of "standard practice" in the debate around climate, as argued by several research studies (Adams and Frost, 2006; Krumdieck, 2013; Loorbach et al., 2016; Loorbach, Frantzeskaki and Avelino, 2017). Furthermore, in 1984 the United Nations decided to establish an independent group of 22 people, selected from members states of both the developing and developed parts of the world, with the aim of identifying the long-term environmental strategies for the international community (Elliott, 1993).
"Our Common Future" - often known as the "Brundtland Report" after its chair, the at the time Prime Minister of Norway, Gro Harlem Brundtland - was published in 1987. The report contains the first definition of sustainable development as a specific link between environment and development, thus defined as "the development that meets needs of the current generation without compromising the ability of future generations to meet their own needs" (p. 43). Some definitions of sustainable development have been given in the years before the one offered by the Brundtland Report, such as the following:

a) "In principle, such an optimal (sustainable growth) policy would seek to maintain an "acceptable" rate of growth in per-capita real incomes without depleting the national capital asset stock or the natural environmental asset stock." (Turner et al., 1988)

b) "The net productivity of biomass (positive mass balance per unit area per unit time) maintained over decades to centuries." (Conway, 1987)

Moreover, other interpretations of the concept of sustainable development were given by different research studies and ideas, as shown below. Surely, these interpretations have been influenced by different disciplines and target areas, providing an interesting contribution to the sustainability debates.

- "A creatively ambiguous phrase . . . an intuitively attractive but slippery concept." (Mitchell, 1997, p. 28)

- “Like motherhood, and God, it is difficult not to approve of it. At the same time, the idea of sustainable development is fraught with contradictions.” (Redclift, 1997, p. 438)

- “It is indistinguishable from the total development of society.” (Barbier, 1987, p. 103)

- “Its very ambiguity enables it to transcend the tensions inherent in its meaning.” (O’Riordan, 1995, p. 21)

- “Sustainable development appears to be an over-used, misunderstood phrase.” (Mawhinney, 2002, p. 5)

The report places sustainable development into the political arena of international development thinking: it has now been translated in more than 24 languages (Finger, 1994) and its meaning continues to be that which is most widely used (Elliott, 1993). Sustainable development is a core concept within the global development policy agenda, and it provides a specific mechanism through which society can interact with the environment without jeopardizing the available resources for the future (Cerin, 2006; Abubakar, 2017; Mensah 2019).

The United Nations Conference on Environment and Development, the “Earth Summit”, took place in Rio de Janeiro, Brazil in 1992 and was the largest ever international conference held at that time (Elliott, 1993).

In the context of development and the environment, a consensus was reached regarding the importance of doing research, taking action and striving for a desirable policy objective. Precisely because of this, throughout the 1990s, the meaning and practice of sustainable development were consistently debated. For instance, relevant attention has been given to several topics, such as the relationship between the environmental condition of rich and poor countries, between those who wished to exploit resources and those who wished to conserve them, and, lastly, between the development needs of current generations and future ones (Elliott 1993; Mawhinney, 2001; McNeill, 2000). The substantial challenges of operationalizing the concept of sustainable development have been clearly defined in the report of WCED:

Critical objectives

- Reviving growth
- Changing the quality of growth
- Meeting essential needs for jobs, food, energy, water and sanitation
- Ensuring a sustainable level of population

- Conserving and enhancing the resource base
- Reorientating technology and managing risk
- Merging environment and economics in decision-making

The pursuit of sustainable development requires:

- A political system that secures effective citizen participation in decision-making
- An economic system that provides for solutions for the tensions arising from disharmonious development
- A production system that respects the obligation to preserve the ecological base for development
- A technological and international system that fosters sustainable patterns of trade and finance
- An administrative system that is flexible and has the capacity for self-correction

These critical objectives were identified in 1987 together with the necessary conditions, encompassing a large breadth and scale of activity. The possibility to guarantee a prosperous, just and secure future depends on new forms of behaviours at all levels and in the interests of all (Elliott, 1993). Thereby, both the first definitions and the subsequent one given by the Commission encompassed the idea that there are three interdependent pillars of sustainable development: environment, economy and society (Savić, Jeremić, & Petrović, 2016).
Barbier, in 1987, presented these pillars as three interlocking circles as seen in the following representation (*Figure 15*).

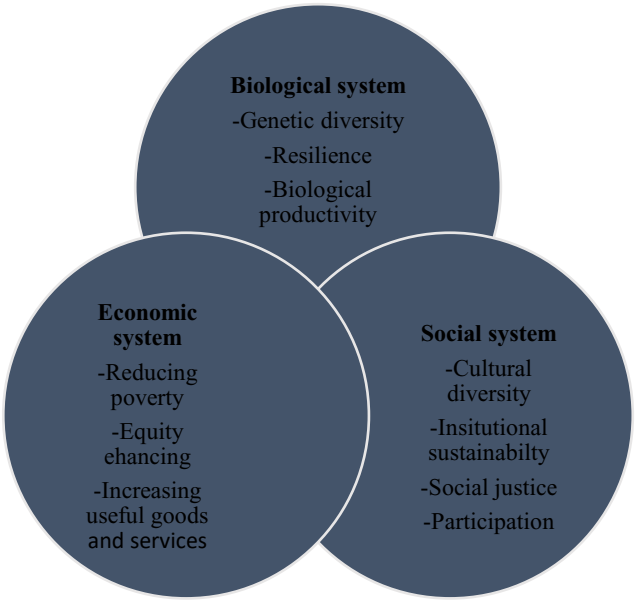

Figure 15_ The objective of sustainable development (Barbier, 1987)

The analysis carried out by Evers (2018) underlined the concept of meeting human development goals together with the ability of acquiring a natural system to provide the natural resources and ecosystem services upon which economy and society depend. Thereby, sustainable development aims at achieving concurrently social progress, environmental equilibrium and economic growth (Gossling and Goidsmiths, 2018; Zhai and Chang, 2019):

Rising interest in sustainable development is a result of the perception of the current concerning conditions of the global human environment (Savić et al., 2016). Sustainable development is a critical and popular strategy that is open to numerous approaches and interpretations. Naturally, a large number of researchers, organizations, institutions and international agencies developed and offered various methodologies and concepts for measuring sustainability. Sustainability indicators emerged to satisfy the requirement of measuring and monitoring sustainable development and its progress, facilitating the decision-making progress by taking into account the three dimensions (Diaz-Sarachaga, Jato-Espino, and CastroFresno, 2018).

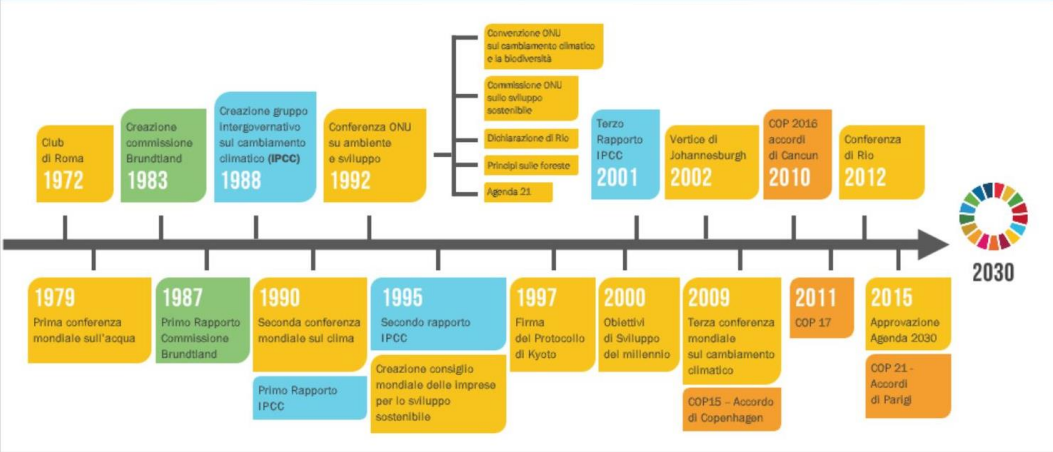

Figure 16_ Milestones in the history that led to the definition of sustainable development and the SDGs (asvis.it/sviluppo-sostenibile)

The Commission on Sustainable Development was instructed to develop and implement national indicators of sustainable development (Tilbury, 2007; UN, 2007). This is the reason why most world leaders approved the UN Millennium Declaration in September 2000 [13] (UN, 2000) including eight Millennium Development Goals (MDGs) to tackle major issues by 2015, which that will be further analysed in the following sections.

The General Assembly, in its resolution 38/161 of 19 December 1983, inter alia, welcomed the establishment of a special commission that should provide a document highlighting the environmental and global issues from the year 2000 onwards, including proposals of sustainable development strategies. The commission later adopted the name *World Commission on Environment and Development*. In the same resolution, the Assembly decided that, with matters within the mandate and purview of the United Nations Environment Programme, the report of the special commission should be primarily considered by the Governing Council of the Programme. This way it may be transmitted to the Assembly together with its comments, and be used as starting draft in preparation of the Environmental Perspective to the Year 2000 and Beyond[14] (*Figure 16*).

3.3 Assessing sustainability through sustainable goals

In 2015, the United Nation Member States adopted the *2030 Agenda for sustainable Development* and its fundamental 17 Sustainable Development goals-SDGs.

Those SDGs are built on decades of work by countries and the UN, involving the UN Department of Economic and Social Affairs. The main steps leading to the definition of the SDGs are the following:

[13] https://www.un.org/millenniumgoals/news.shtml
[14] (sustainabledevelopment.un.org/milestones/wced)

At the United Nations Conference on Environment and Development in Rio de Janeiro (1992) the measures for evaluating sustainable development were discussed. During this event, also known as *Agenda 21*, the "systems for monitoring and evaluating progress towards achieving sustainable development by adopting indicators that measure changes across economic, social and environmental dimensions" were discussed (UN, 1992; Strezov, Evans, and Evans 2017).

Defining and measuring sustainable development at an operational level is one of the greatest challenges of contemporary environmental, social and economic policies. Several attempts to measure sustainability have been made by scientists (environmental), non-governmental organizations (NGOs), national states and international organizations. Such attempts include related indicator frameworks and indicator systems, which are more focused on the performance evaluation procedures, and aggregated indices of sustainable development or related phenomena such as environmental performance, human development, happiness, etc. The toughest challenge of measuring sustainability is to include all its relevant dimensions in the evaluation process.

According to Hezri and Dovers (2006, p. 87), the main approaches to develop sustainability goals and indicators are as follows: (1) extended national accounts, (2) bio-physical accounts, (3) weighted indices, (4) eco-efficiency and dematerialization approaches and (5) indicator sets. According to this, at the beginning of the century, UN member states drew up a development agenda around eight Millennium Development Goals (MDGs).

3.3.1 The Millennium Development Goals- MDGs

The Millennium Development Goals (MDGs) are composed by 8 goals, 18 targets and 48 indicators (changed over the period and eventually reached 60 indicators). They have been identified within the 21 Agenda adopted by the United Nations General Assembly in 2000. The participating 189 member states had met at the dawn of a new millennium, to reaffirm our faith in the Organisation and its Charter as "indispensable foundations of a more peaceful, prosperous and just world" (UN, 2000).

MDGs involved:

1) eradicating extreme poverty and hunger, 2) achieving universal primary education, 3) promoting gender equality and empowering women, 4) reducing maternal and child mortality, 5) improving maternal health, 6) combating HIV/AIDS, malaria and other diseases and 7) ensuring environmental sustainability all within a context of 8) a global partnership for development. These goals were composed of many specific and monitorable targets to be achieved by 2015 (*Table*

10). Generally, they concern poverty, disease, hunger, gender inequality, disadvantaged schooling and environmental issues. Through the set of goals and measurable targets, the MDGs helped to promote a sense of awareness, political accountability, improved metrics and social feedback, by generating incentives to improve performances (Sachs, 2012). The MDGs were considered as "unprecedented in the range of goals and targets chosen, in the recognition that most are interconnected, and in the public commitment from international agencies that they will be judged by whether these goals and targets are achieved" (Satterthwaite, 2003). In addition, MDGs have marked a historic and powerful strategy of global mobilization to achieve a set of key social priorities worldwide (Sachs, 2012).

Table 10_ The millennium development goals and targets (developmentgoals.org)

Goal		Target
1	**To eradicate extreme poverty and hunger**	1) To halve, between 1990 and 2015, the proportion of people whose income is less than US$1 a day
		2) To halve, between 1990 and 2015, the proportion of people who suffer from hunger
2	**To achieve universal primary education**	3) To ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling
3	**To promote gender equality and empower women**	4) To eliminate gender disparity in primary and secondary education, preferably by 2005 and in all levels of education no later than 2015
4	**To reduce child mortality**	5) To reduce by two-thirds, between 1990 and 2015, the under-five mortality rate
5	**To improve maternal health**	6) To reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio
6	**To combat HIV/Aids, malaria and other diseases**	7) To have halted by 2015 and begun to reverse the spread of HIV/Aids
		8) To have halted by 2015 and begun to reverse the incidence of malaria and other major diseases
7	**To ensure environmental sustainability**	9) To integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources
		10) To halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation

		11) To have achieved, by 2020, a significant improvement in the lives of at least 100 million slum dwellers
8	**To develop a global partnership for development**	12) Develop further an open, rule-based, predictable, non-discriminatory trading and financial system
		13) To address the special needs of the least developed countries
		14) To address the special needs of landlocked countries and small island developing states
		15) To deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long run
		16)In cooperation with developing countries, to develop and implement strategies for decent and productive work for youth
		17) In cooperation with pharmaceutical companies, to provide access to affordable, essential drugs in developing countries
		18 In cooperation with the private sector, to make available the benefits of new technologies, especially information and communication

The 2012 analysis reported by Sachs in *Lancet,* shows interesting considerations on the use and enforceability of MDGs all over the world, pointing out the differences and difficulties between rich and poor countries.

The achievement of these goals has depended on multiple variables, such as countries, regions, cities. For instance, the economic growth in China has cut the poverty rate, effectively halving it between 1990 and 2010 (Sachs, 2012).

However, even though some countries have managed to reach all or most of the MDGs, others were only able to reach very few.

For countries with less economic potential, it has been hard to achieve these goals, the shortfall represents indeed a set of operational failures that involve many stakeholders, in both poor and rich countries. Promises of official development assistance by rich countries, for example, have not been kept.

Moreover, for more than a decade, the MDGs have remained a focus of global policy debate and national policy planning. For instance, they have been implemented into the work of non-governmental organizations and were taught to students at all levels of education (Sachs, 2012).

Furthermore, MDGs were used as tools to advocate improved services for the urban poor. However, problems emerged with both the framework and implementation

(Fehling, Nelson, & Venkatapuram, 2013; Klopp and Petretta, 2017). First of all, although recommended by the task force, the urban poor were often not involved in the interventions designed to support them, and their voices were often missing at the levels of local government where action was most needed (Hasan, Patel, & Satterthwaite, 2005). Secondly, urban poverty indicators were very problematic, consistently discounting the scale and depth of poverty in the most affluent cities (Satterthwaite, 2003). Thirdly, economic, social and environmental aspects have not been included in the MDGs (Ki-Moon, 2013). Lastly, the monitoring and reviewing of the MDGs did not begin until five years after the targets were employed and even then, data has often been delayed up to three or even more years (Ki-Moon, 2014). In a world already facing such a dangerous climate change and other critical environmental ills, there is also widespread understanding that worldwide environmental objectives need a higher profile alongside the poverty-reduction objectives. For these reasons, the world's governments seem poised to adopt a new round of global goals to follow the 15 years of the MDG period, the Sustainable Development Goals

3.3.2 The 2030 Agenda for sustainable development

On the morning of September 25 at the fourth plenary meeting of the 70th session of the United Nations General Assembly, nations adopted resolution A/RES/70/1, Transforming Our World: The 2030 Agenda for Sustainable Development. Such Agenda is defined as a plan of action for people, the planet and prosperity. The implementation of this plan is achievable only with a collaborative partnership between all countries and stakeholders. Within this Agenda, the necessity to take bold and transformative steps which are urgently needed to shift the world on to a sustainable and resilient path is to be emphasized (UN, 2015). In such regards, the 2030 Agenda declared in paragraph 2:

> *"On behalf of the peoples we serve, we have adopted a historic decision on a comprehensive, far-reaching and people-centred set of universal and transformative Goals and targets. We commit ourselves to working tirelessly for the full implementation of this Agenda by 2030. We recognize that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development. We are committed to achieving sustainable development in its three dimensions – economic, social and environmental – in a balanced and integrated manner. We will also build upon the achievements of the Millennium*

> *Development Goals and seek to address their unfinished business*" (UN, 2015).

In substance, this Agenda commits to being ambitious and universal through the announcement of the SDGs, which effectively take the place of the MDGs to complete what they did not achieve and to balance the dimension of sustainable development: economic, social and environmental. Such goals and targets will motivate action over the next 15 years in core areas of critical importance to humanity and the planet. Effectively, these core areas entail: people, the planet, prosperity, peace and partnership. For people, the Agenda determined to end poverty and hunger, in all their forms and dimensions, ensuring that all human beings can fulfil their potential in dignity and equality and in a healthy environment. For what concerns the planet, protection from its own degradation was determined, implicated through sustainable consumption and production. By sustainably managing its natural resources and taking serious action on climate change, that the planet can satisfy the needs of the present and future generations. In terms of prosperity, it was agreed to ensure that all human beings can enjoy prosperous and fulfilling lives. In order to do so, economic, social and technological progress must occur in harmony with nature. Furthermore, Peace may be implemented by fostering peaceful, just and inclusive societies which are free from fear and violence. I strongly believe there can be no sustainable development without peace and no peace without sustainable development. Finally, partnership was encouraged to mobilize the means required to implement this Agenda through a strengthened Global Partnership for Sustainable Development, based on a spirit of reinforced global solidarity, particularly focusing on the needs of the poorest and most vulnerable and with the participation of all countries, all stakeholders and all people. Moreover, paragraph 5 also highlighted the main aims of this new Agenda and the relevance of the new established goals:

> "*This is an Agenda of unprecedented scope and significance. It is accepted by all countries and is applicable to all, taking into account different national realities, capacities and levels of development and respecting national policies and priorities. These are universal goals and targets which involve the entire world, developed and developing countries alike. They are integrated and indivisible and balance the three dimensions of sustainable development*."

The identification and subsequent establishment of these new goals and targets is the result of over two years of intensive public consultation and engagement with

stakeholders and civil society all around the world, taking into account the voices of the poorest and most vulnerable people.

3.3.3 The Sustainable Development Goals- SDGs

In 2015, the United Nation Member States adopted the 2030 Agenda for sustainable Development, with the 17 Sustainable Development goals-SDGs as its core.
Those SDGs are built on decades of work by countries and the UN, involving the UN Department of Economic and Social Affairs. As reported in the official site of SDGs (sdgs.un.org/goals), the main steps leading to the definition of the SDGs are as follows:

- At the Earth Summit in Rio de Janeiro (Brazil), in June 1992, more than 178 countries adopted Agenda 21, a global action plan to build a worldwide partnership for sustainable development to improve people's lives and protect the environment.
- The Millennium Declaration was unanimously endorsed by the Member States at the Millennium Summit in September 2000 at the United Nations headquarters in New York. The summit resulted in the development of eight Millennium Development Goals (MDGs) to reduce extreme poverty by 2015.
- The Johannesburg Declaration on Sustainable Development and Plan of Implementation, officially implemented at the World Summit on Sustainable Development.
- in South Africa in 2002, restated the global community's efforts to eradicate poverty and the environment. In addition, they built upon Agenda 21 and the Millennium Declaration, including a stronger emphasis on multilateral partnerships.
- At the United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil, in June 2012, Member States officialised the Outcome Document "The Future We Want" in which they decided, among other things, to initiate a process to develop a set of Sustainable Development Goals (SDGs) based on the MDGs and to establish the United Nations High Level Political Forum on Sustainable Development. The outcome of Rio+20 also contained other measures for the implementation of sustainable development, including mandates for future work programmes in development finance, small island developing states and more.
- In 2013, the General Assembly established a 30-member Open Working Group to advance a proposal on the SDGs.
- In January 2015, the General Assembly started the negotiation process for the post-2015 development agenda. The ongoing process culminated in the

successful endorsement of the 2030 Agenda for Sustainable Development, with 17 SDGs at its core, at the United Nations Summit on Sustainable Development in September 2015.

- 2015 was a pivotal year for international multilateralism and policy-making, with the establishment of several important agreements:
    - Sendai Framework for Disaster Risk Reduction (March 2015) o Addis Ababa Action Agenda on Financing for Development (July 2015) o Transforming our world: the 2030 Agenda for Sustainable Development with its 17 SDGs was adopted at the UN Sustainable Development Summit in New York in September 2015. o Paris Agreement on Climate Change (December 2015)
- Currently, the annual High-Level Political Forum on Sustainable Development acts as the central UN platform for the follow-up and revision of the SDGs.

Hence, on the 25th September 2015, the UN General Assembly, adopted the 2030 Agenda per the sustainable development, providing strategic directions to support the future development of cities and communities, identifying 17 SDGs, 169 targets and 232 quantifiable indicators.

SDGs are the blueprint to achieve a better and more sustainable future for all since they address global challenges, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. The Goals interconnect and to ensure every member's inclusion, countries must achieve each goal and target by 2030. To clarify, SDGs were defined subsequently after MDGs. In a critical analysis Parnell (2016) outlines five main points in which the SDGs differ from the MDGs (*Table 11*). First of all, the goals are universal, applying to every area not only in "poor" countries. Secondly, the economic, social and environmental dimensions of sustainable development are unambiguous, and more integrated together with a solid identification. Third, there is an acknowledgement of the need to harness technological innovation to create better data sources and monitoring at different scales. Finally, global development is expressly connected to global finance (Klopp and Petretta, 2017).

Table 11_ Comparison between MDGs and SDGs (Klopp and Petretta, 2017)

MDGs	SDGs
2000-2015	2015-2030
8 goals, 18 targets, 48 indicators	17 goals, 169 targets, 230 indicators
Focused on "poor" nations	Universal, global

Data lagging and spotty. Mostly surveys, census.	Data still lagging but exploration of new sources - “data revolution” incl. open data, geospatial data, citizen scientists, etc.
Voluntary, non-binding	Voluntary, non-binding
No comprehensive monitoring or analysis of MDG spending (mostly government budgets and Official Development Assistance)	Linked to global financing framework from the beginning (Addis Ababa Action Agenda) although funding mechanisms and monitoring system still vague
Primary focus was eradicating poverty	Explicit focus on holistic sustainable development including environmental goals
MDG 7 Target 11 refers to improving the lives of at least 100 million slum dwellers	Stand, alone UrbanSDG Goal 11, cities recognized as “pathways to sustainable development”, more expansive role for urban planning, design and architecture
Local governments absent from formal process	Local governments still absent with no formal role but more involved in advocacy
Excluded people, top-down	Calls for inclusion, participatory processes

SDGs are considered a complement of the experiences between 2000 and 2015. They regard worldwide sustainable initiatives and goals to achieve within 2030, some in 2020, to guarantee development for future generations (https://sdgs.un.org/goals).

SDGs are respectively: 1-No Poverty, 2- Zero Hunger, 3-Good Health and Wellbeing, 4-Quality Education, 5-Gender Equality, 6-Clean Water and Sanitation, 7Affordable and Clean Energy, 8-Decent Work and Economic Growth, 9-Industry, Innovation and Infrastructure, 10-Reduced Inequalities, 11-Sustainable Cities and Communities, 12-Responsible Consumption and Production, 13-Climate Action, 14-Life Below Water, 15-Life on Land, 16-Peace, Justice and Strong Institutions, 17-Partnerships for The Goals (T*able 12*).

T*able 12_ The Sustainable Development Goals established in 2015 by the UN in 2030 Agenda*

Goals		Description
1	**No poverty**	End poverty in all its forms everywhere
2	**Zero hunger**	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	**Good health and well being**	Ensure healthy lives and promote well-being for all at all ages
4	**Quality education**	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	**Gender equality**	Achieve gender equality and empower all women and girls
6	**Clean water and sanitation**	Ensure availability and sustainable management of water and sanitation for all
7	**Affordable and clean energy**	Ensure access to affordable, reliable, sustainable and modern energy for all
8	**Decent work and energy growth**	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	**Industry, innovations and infrastructure**	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	**Reduced inequalities**	Reduce inequality within and among countries
11	**Sustainable cities and communities**	Make cities and human settlements inclusive, safe, resilient and sustainable
12	**Responsible consumption and production**	Ensure sustainable consumption and production patterns
13	**Climate action**	Take urgent action to combat climate change and its impacts
14	**Life below water**	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	**Life on land**	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	**Peace, justice and strong institution**	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

17	**Partnership for the goals**	Strengthen the means of implementation and revitalize the global partnership for sustainable development

3.3.4 SDG11 – Sustainable cities and communities

This research is focused on SDG 11-Sustainable Cities and Communities: cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. With the number of people living within cities expected to rise to 5 billion people by 2030, efficient urban planning and management practices must be in place to deal with the challenges brought by urbanization. Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing, declining infrastructure and rising air pollution within cities. Rapid urbanization challenges, such as the safe removal and management of solid waste within cities, can be overcome in ways that allow them to continue to thrive and grow while improving resource use and reducing pollution and poverty. One example is the increase in municipal waste collection. A future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation and more, is a crucial requirement (www.un.org/sustainabledevelopment). In relation to the description of SDGs, it is important to further explain the role of goals, *targets* and *indicators*.

Goals entail the list of the 17 objectives to achieve until 2030 while the *targets* are the guidelines that better describe the goal itself to reach sustainable development.

Furthermore, *indicators* are considered communication tools that help transmit information related to ongoing processes, and as elements of evidence-based policymaking (Flückiger, and Seth, 2016). Indicator-based sustainability communication helps interpret the complexity and uncertainty of sustainable development, informing the different actors involved in sustainable development processes on the current progress.

The question of what may be evaluated with the SDG *indicators* is also part of controversial critiques, which argue that the radical change that is needed for sustainability is not reflected in the current conception of the SDG *indicators*.

The 2030 Agenda makes SDGs operational, requiring each country to translate and apply those objectives in relation to their specific context. This operation is crucial: it should reflect the characteristics of every single country, as it is not a universal translation. Providing successful translations of SDG indicators is, from the global to the national level vital, and national governments are key actors in this process (Biermann, Kanie, and Kim 2017; Tosun & Leininger, 2017). Nonetheless, at the same time, SDG implementation at the local level likewise must be employed by municipal actors. Here, a specific challenge stands out: no clear guidelines have been arranged on how to transfer national sustainability goals to the urban level, and

how to successfully implement SDGs in cities. Hence, the aim is to evaluate how the indicators were set for the urban areas and the environment in terms of SDGs.
In conclusion, the development of an appropriate indicator system for cities will depend on the embedded capacities to share and learn across contexts and work collaboratively with associations, municipalities, industries, societies and where it may be possible, citizens. The contextualization to the urban context presents a major challenge, and issues such as data accountability as well as data provision and collection on the different spatial scales from city to national level as well as that civil society should also be involved in SDG implementation, as monitoring requires new data assessment, quality, and monitoring approaches. SDG 11 has 7 targets to be achieved by 2030 as shown in *Table 13*.

Table 13_ List of Targets and Indicators of SDG11[15]

TARGETS	INDICATORS
11.1 **By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums**	11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing
11.2 **By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons**	11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities
11.3 **By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries**	11.3.1 Ratio of land consumption rate to population growth rate
	11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically
11.4 **Strengthen efforts to protect and safeguard the world's cultural and natural heritage**	11.4.1 Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and

[15] *sustainabledevelopment.un.org/sdg11*

	World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship)
11.5 **By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations**	11.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
	11.5.2 Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters
11.6 **By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management**	11.6.1 Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities
	11.6.2 Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)
11.7 **By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities**	11.7.1 Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities
	11.7.2 Proportion of persons victim of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months
11.a **Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning**	11.a.1 Proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by size of city

11.b **By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels**	11.b.1 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
	11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
11.c **Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials**	11.c.1 Proportion of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings utilizing local materials

Following the table of SDG 11 with its relatives' targets, goals, it's possible to define some characteristics to evaluate a real and concrete impact, of their indicators, in urban contexts. The question is how to evaluate the indicators, for instance in terms of numbers, percentages, hours, km2, or sqm2.

As mentioned above, it is not easy to transfer the worldwide guidelines indicators to an immediate application in local daily life. By establishing measurements, it is easier to see developments and changes occurring over time, evaluating improvements in terms of achieving the goals.

The key words selection enables specific research for each indicator. This way, it becomes easier to find scientific articles and publications closely linked to the indicator's description. In concerns of targeting people, it is only appropriate to bear in mind how the indicators generally refer to everyone, although they particularly focus on women, children, the elderly and people with disabilities, without any form of discrimination, in terms of sex, age or race (*Table 14*). SDG indicators present a realistic topic in both practice and research. Scientists see the need to devise metrics, establish monitoring mechanisms, evaluate progress, enhance infrastructure, and standardize and verify data (Lu et al., 2015) which not only holds for SDG 11 indicators but also for the employment of indicators in general (Koch & Krellenberg, 2018).

Table 14_ The list of SDG 11 with indicator's values keywords, target people and the measurement

INDICATOR'S DESCRIPTION	INDICATOR'S VALUES keywords	TARGET PEOPLE	How to evaluate the indicator?
SDG11.2	SDG11.2.1		
"By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all".	• Convenient access • Public transport • Sustainable transport • Affordable access • Safe access	Convenient access for everyone, especially by: • sex • age • person with disabilities In terms of % and/or numbers	Sustainable transports: • CO2 • Frequency and hours • Urban network (km2, sqm2) • Accessibility (within 500 m walking distance of a bus stop and within 1,000 m of a railway and/or ferry terminal
SDG11.3	SDG11.3.1		
"By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, …"	• Inclusive urbanizations • Sustainable urbanizations • Land consumption • Population growth	Population growth rate in specific cities or urban areas (difference in %)	The ratio between: • % of land • % of population growth rate
	SDG 11.3.2		
	• Direct participation • Management integration • Participatory management • Democratic participation (Expressions used in terms of urban planning and management)	Civil society: • People components (what are the members of a civil society)	Map the parts of cities where there is a direct participation, in terms of: • Number of public events dedicated to participation • Number of participants instead of

			city population
SGD 11.6	SGD 11.6.1		
"By 2030, reduce the adverse per capita environmental impact of cities…"	• Environmental impact • Urban solid waste • Discharge out • Waste management	Civil society: • People components (what are the members of a civil society)	In terms of waste management based on the total amount of waste: • Rubbish (kg) per person • Number of landfills • Ratio between collected waste and appropriate landfills
	SGD 11.6.2		
	• Air quality • PM 2,5 • PM 10	Entire urban society, more drivers with own cars	In terms of air quality: • PM 2,5 per year • PM 10 per year
SDG 11.7	SDG 11.7.1		
"By 2030, provide universal access to safe, inclusive and accessible, green and public spaces…"	• Green areas • Public spaces • Inclusive public access • Build up areas	To involve all kind of people, especially, • Women • Children • Older people • People with disabilities	Quantity of green and public areas open to the citizens, in terms of: • Number of areas • Sqm2 or km2 • Access hours • Access to open public spaces (defined as spaces within 400 m walking distance of their residence)
	SDG 11.7.2		

	• Green areas • Public spaces • Safe public access	People victim of physical or sexual harassment, in the previous 12 months by: • Sex • Age • Disability status	Proportion of people victims (if there is) of physical or sexual harassment, in public areas: • Numbers of harassment • Ratio based on the previous years • % of victim's genre and sex • % of victim's age

Figure 17 shows one more graphical representation of targets and indicators of SDG11. This figure reports the indicators' measurement in which it is possible to analyse the targets and goals. These indicators are converted into percentages, ratios, areas and surfaces, weights and numbers.

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11.1
Ensure housing access for all

% of urban population
- living in slums
- informal settlements or inadequate housing

11.2
Convenient access to public transport

- CO2
- Frequency and hours
- Urban network (km2, sqm2)
- Accessibility (within 500 m walking distance of a bus stop and within 1,000 m of a railway and/or ferry terminal

11.3
Inclusive and sustainable urbanization

11.3.1) The ratio between:
- % of land
- % of population growth rate

11.3.2) Urban participation, in terms of:
- Number of public events dedicated to participation
- Number of participants instead of city population

11.4
Protect the world's cultural and natural heritage

€ per capita spent on preservation, protection and conservation of all cultural and natural heritage, by
- type of heritage
- level of government
- type of expenditure
- type of private funding

11.5
Reduce the number of deaths

11.5.1
- Number of death and missing persons
- Directly affected persons attributed to disasters (per 100,000 population)

11.5.2) Economic Loss in terms of
- damage to critical infrastructure
- number of disruptions attributed to disasters

11.6
Reduce environmental impact of cities

11.6.1) Waste management
- Rubbish (kg) per person

11.6.2) Air quality
- PM 2,5 per year
- PM 10 per year

11.7
Safe, inclusive and accessible access to green and public spaces

11.7.1)
- Number and surface (km2)
- Access hours and to open public spaces (400 m walking distance of their residence)

11.7.2) Proportion of people victim
- Numbers of harassment
- Ratio based on the previous years
- % of victim's genre, sex and age

11.a
Support links between urban, peri-urban and rural areas

11.a.1
- % of population living in cities that implement urban and regional development plans integrating population projections and resource needs

11.b
the Sendai Framework for Disaster Risk Reduction 2015–2030 (disaster risk management at all levels)

11.b.1
- Number of countries that adopt and implement national disaster risk reduction strategies in SFDRR

11.b.2
- % of local governments that adopt and implement local with national strategies

11.c
Build sustainable and resilient buildings with local materials

11.c.1
% of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings utilizing local materials

Figure 17_ Author's re-elaboration of the targets and indicators for SDG1. The targets circled in red are the ones of most interest for this thesis

3.3.4 The KnowSDG Platform

An international debate along with multiple research efforts to identify possible synergies and trade-offs between goals is underway. For this reason, the Joint Research Center (JRC) of the European Commission has developed the *KnowSDGs* platform (Knowledge base for the Sustainable Development Goals). This online platform provides tools to organize knowledge related to policies, indicators, methods and data supporting the implementation of the SDGs[16]. *KnowSDGs* is incorporated in the list of JRC database tools and it is the only one to deal with all 17 SDGs. Within this platform, it is possible to explore the available interactive tools to learn more on specific SDGs. The tools are respectively: SDG policy Mapping, EC models for SDGs, SDG Interlinkages and Consumer Footprint Calculator. Among these tools, the Interlinkages tool was found to be the most suitable for studying the relationships between the different goals. JRC *Interlinkages* tools are indeed composed by the EnablingSDGs tool and the Interlinkages visualization tool. The first supports policymakers in the identification of interlinkages (synergies and trade-offs) and interactions between different SDGs. Its aim is to assess impacts of different policy choices, highlighting second-order effects and potential unintentional consequences of the policy proposals. Generally, this tool is used to collect expert's evaluations, engaging them in a dialogue to map the key interactions across SDGs in a particular context (knowsdgs.jrc.ec.europa.eu/intro-interlinkages). In contrast, the Interlinkages visualization tool, is specific to the identification of synergies and trade-offs between goals. A more detailed overview is explained in the following paragraph.

3.3.4.1 Interlinkages visualization tool

Since many of the goals included in the SDGs are multidimensional and cover the three main dimensions of sustainability, many synergies, complementarities but also trade-offs can exist among the goals. The interlinkages tool is the most suitable to identify the relationship among the goals in terms of synergies or tradeoffs (*Figure 18*). Nevertheless, the lack of a clear definition of the term *interlinkages* allows different responses towards its meaning and possible examples.
According to Nilsson et al. (2018), the 2030 Agenda emphasizes the relevance to understanding interlinkages between urban areas and the implementation of the SDGs. Interactions among different kinds of actors are necessary to build partnerships, and sometimes this is associated with the understanding of how the interactions appear between policy issues or sectors they represent. This kind of

[16] knowsdgs.jrc.ec.europa.eu/interlinkages/info

interaction can be both positive or negative. Commonly, positive interactions provide the prospect to identifying co-benefits that enable achieving outcomes at a lower cost or with enhanced impact, through coordination of action (Nilsson et al., 2018). For instance, (McCollum et al., 2018) showed how simultaneously targeting energy security, air pollution and climate change in energy systems could achieve all three goals at only slightly higher cost than achieving just the climate change goal alone.

Meanwhile negative interactions are also possible, as certain interventions may cause positive effects for some SDGs but also negative for others, defined as trade-offs. Considering the context of the UN SDGs framework, the interlinkages are mainly identified between goal and goal; target and target; indicator and indicator; environmental, socio-economic pillars of sustainability (Miola et al., 2019).

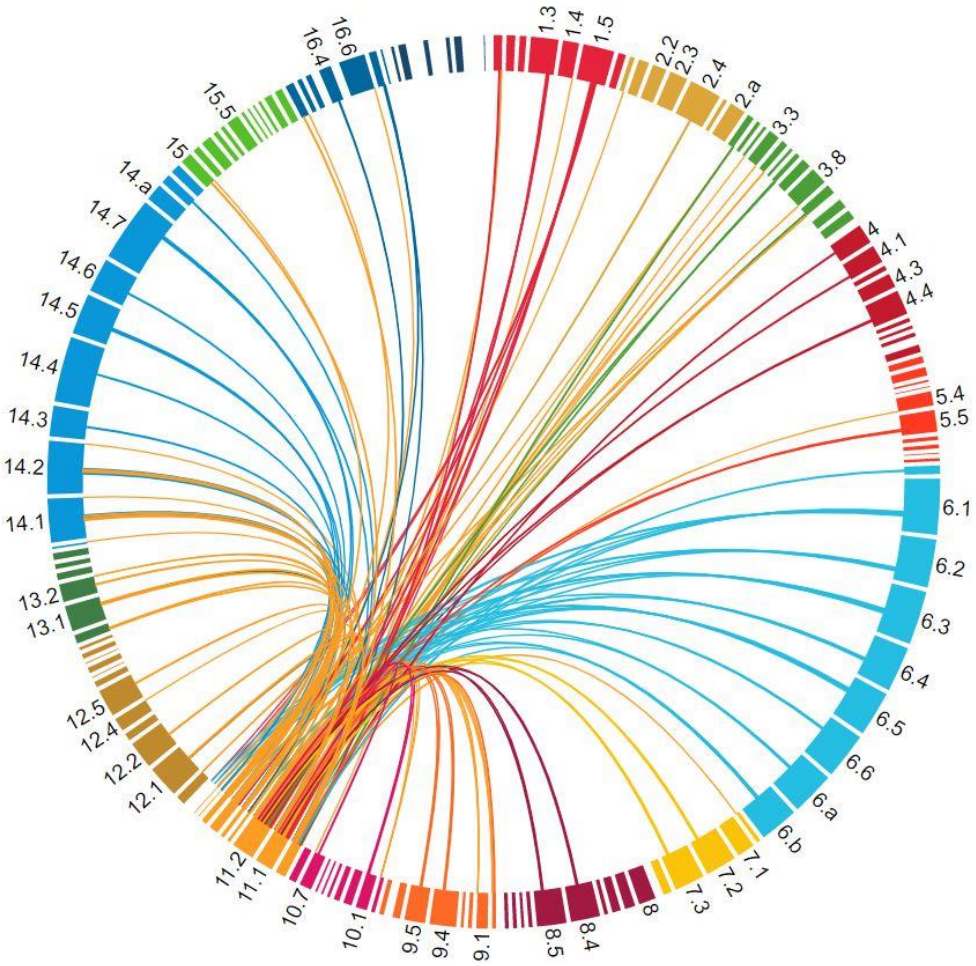

Figure 18_ Interlinkages visualization tool of SDG 11's chord synergies

The interlinkages may depend on the context or be defined in more general terms. Additionally, they can be applied at a different level (local, national or global) and become effective both/either in the short and in the long term. This tool also allows

users to rapidly realise which interlinkages hold strong connections to the literature (Miola et al., 2019).

According to the literature, the interlinkages have been generally identified and analyzed through different methodologies, approaches, assumptions, and results summarized in 5 main methodological approaches (Miola et al., 2019):

1) the *linguistic approach*, characterized by the choice of selected keywords identified in previous research (Le Blanc, 2015; Coopman et al., 2016; Stafford-Smith et al., 2017);
2) the *literature-based approach*, which concerns the identification of the interlinkages in scientific literature, mostly with no direct references to the SDGs (Boas, 2016; Karnib, 2017; Mainali et al., 2018). This kind of approach is defined as an exploratory attitude to investigate previous and ongoing research;
3) the *argumentative/expert judgement approach* is based on argumentative/expert judgment, which connects targets according to the concepts involved. ICSU (2017) and Nilsson et al. (2016) set interlinkages on a 7-point scale from -3 (cancellation) to +3 (indivisible) passing by 0 (neutral);
4) the *quantitative approach* attempts to establish interlinkages between goals and targets through the analysis of the respective indicators, using a historical time series of data for two groups of indicators (Eurostat, 2018);
5) finally, the *modelling complex system of interactions* can help to understand the interdependencies between the variables.

From this, it appears that all these approaches, which are recognized in the literature, have no specific tool for modelling SDGs interactions. Therefore, maybe it may be convenient to adapt existing ones and to expand them for future researches (Miola et al., 2019). The JRC defined the interlinkages tool for the KnowSDGs platform according to the literature-based approach, researched in the SCOPUS database. The analysis provided in the report (Miola et al., 2019), after refining the steps, shows 187 documents to which 33 others have been added documents from google search by applying the same keywords. The results drawn from this study show that all 17 SDGs were covered by the interlinkages database, some more than others (such as SDG 6 and SDG 14 instead of SDG 16 and SDG 17 which had the lowest number of entries).

In terms of interlinkages, the analysis shows that based on 3490 total entries identified, the majority belongs to positive interactions, 2548 synergies, while the remaining 942 are identified as trade-offs. Focusing on the analysed literature review, it appears that most of the identified papers put a stronger emphasis on potential synergies instead of trade-offs, as identified by Vladimirova et al. (2016),

IGES (2017), ESTAT (2017) and SDSN (2015), which presented synergies without paying attention to potential trade-offs. The conclusion which may be drawn from this analysis reveals that, the current debate regarding the covering of all the SDGs, requires the database to be extended, in order to provide more sufficient and thorough data on interlinkages (Miola et al., 2019). *Figure 19* shows an example of potential synergies of SDG11 with other goals.

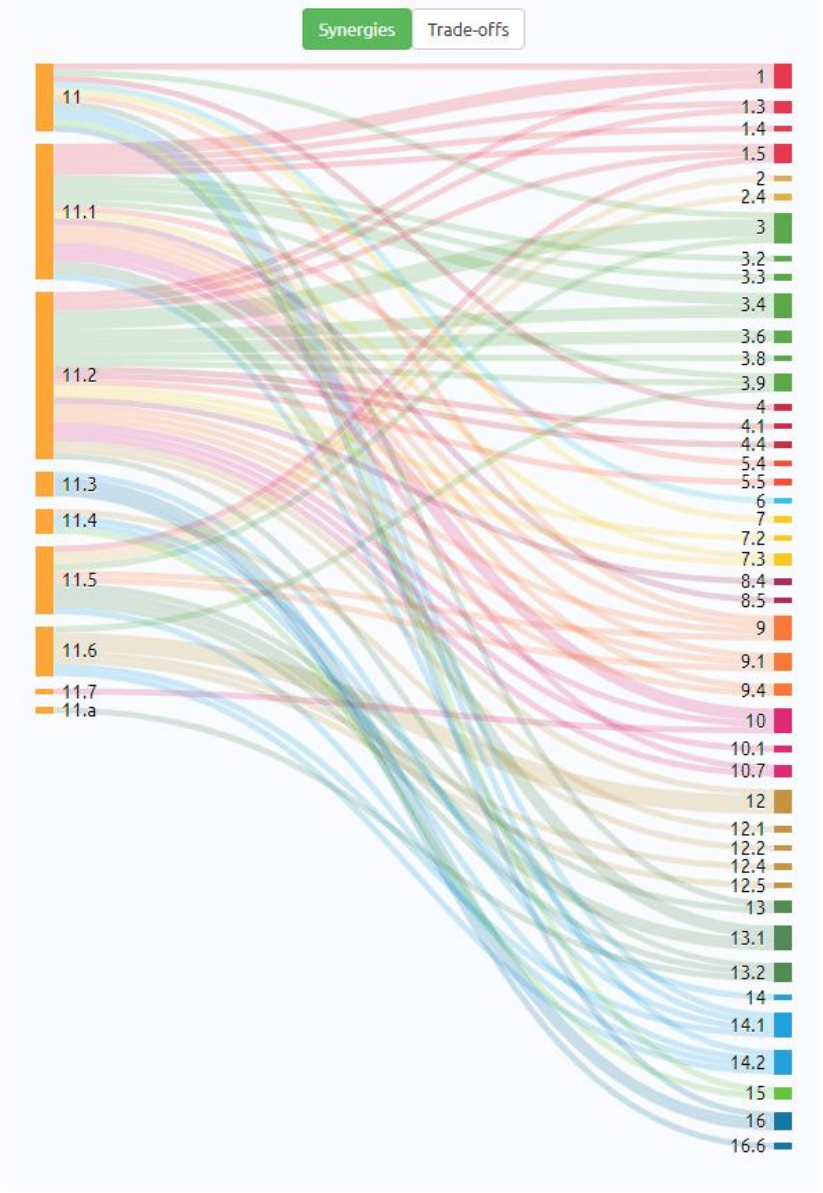

Figure 19_ Example of potential synergies identified for the targets of SDG11 reported in the tool of interlinkages of the KnowSDG platform

Finally, the visualization tool previously discussed will be employed.in the analytical flow chart to assess the interlinkages among the goals addressed in serious games. As mentioned

at the beginning of this chapter, this tool seemed to be, among those available, the most suitable for the purpose of the research of this thesis: that of identifying possible synergies or trade-offs that may occur between sustainable projects, actions or initiatives that have been developed in serious games.
The following two chapters, which will focus mainly on sustainable education, sustainability serious games and learning by doing, will serve to introduce the games which will be analysed through the flow chart. Such serious games will finally be selected and further analysed in Chapter 6.

Chapter 4

Education for sustainable development and a new classification of serious games

Chapters 2 and Chapter 3 provided an analysis of the literature review as a basis for contextualizing the use and application of serious games for sustainable development. They also outlined some of the approaches that are being taken with serious games to spread knowledge in an innovative and engagement way. What emerges from the analysis of the literature review is a lack of information on how serious games convey knowledge about sustainability as an educational tool. For this reason, Chapter 4 is entirely dedicated to the concept of Education for Sustainable Development-ESD and proposes a new classification of sustainable serious games.

The aim is to answer the research question introduced in Chapter 1, which is set out below and explained in more detail: how can serious games be used to spread knowledge on sustainability issues?

Since the previous chapters report the main characteristics and the application fields of serious games, this chapter attempts two main tasks. The first task is to better contextualise serious games among the educational tools that support sustainable development. The second task is to take a snapshot of the panorama of sustainable

serious games currently available on the market. For this reason, I conducted a new research study with the aim of classifying games according to the SDGs addressed within their storylines.
The objective of this classification is not only to create a list of serious games available but also to recognise and identify which SDGs are addressed. Previous classifications have analysed and classified sustainable serious games according to target audience, genre, type and subject matter, so the focus of this new study is to identify the relations with SDGs.
The results of this new classification indicate that there are links between games' subject matter and SDGs. The SDGs most frequently discussed in the ranked serious games are respectively SDG 12- Responsible Consumption and Production, SDG 11-Sustainbale cities and Communities and SDG 15- Life on land.

4.1 Education for Sustainable Development

In 2005 the United Nations declared a Decade of Education for Sustainable Development until 2014 and through the United Nations University, among other initiatives, it established Regional Centers of Expertise (RCEs) on Education for Sustainable Development (ESD) in all countries of the world (Arbuthnott, 2009).
The field of ESD, deriving from Environmental Education (EE), is defined as a student-centered educational area that aims at motivating pupils and young people to become actively involved in the learning process for environmental and societal issues. EE/ESD is constantly seeking creative pedagogical approaches and methods that can attract and engage pupils and young people to its subject of study.
Since the concept of sustainable development was defined in 1987 it has attracted more and more attention from researchers over the years. Efforts began with raising awareness, followed by experimentation and finally, implementation of good practice for knowledge spreading (Laurie et al., 2016).
As suggested by Jickling (1992), a continuous critical review between sustainable development and environmental education is necessary to strengthen this relationship.
There are several applications, such as programs, classes, assignments or exercises, for ESD programs that. ESD curricula should include social science courses to educate students on effective behavior change strategies (Arbuthnott, 2009).
Moreover, Arbuthnott (2009) added that the introduction of educational programs that target specific topics, such as transportation, food, recycling, soil maintenance, energy consumption, environment, etc. will help students to frame more specific intentions in the relevant areas (Abrahamse et al. 2007; Kempton, Darley, and Stern 1992; Guagnano, Stern, and Dietz 1995; Schultz and Stuart 2010; Vining and Ebreo 1992; Joireman, Van Lange, and Van Vugt 2004).

Providing quality education is a complex issue partially because the concept of quality in education is in a perpetual state of evolution (Laurie et al., 2016). “Yet, the definition of quality education is constantly evolving and is always contextual. There is no one definition, list of criteria, definitive curriculum, or list of topics that comprise a quality education. Quality education is a dynamic concept that changes and evolves with time and is modified according to the social, economic and environmental contexts. Because quality education must be locally relevant and culturally appropriate, quality education will take many forms around the world” (UNESCO, 2005, p. 1).

From an institutional standpoint, the concept of education has always played a key role in the initiatives carried out by the United Nations since the creation of UNESCO (United Nations Educational, Scientific and Cultural Organization) less than a month after the official creation and launch of the United Nation in 1945 (Décamps, Barbat, Carteron, Hands, & Parkes, 2017). The mission of UNESCO is to contribute to raising the building of peace, the eradication of poverty, sustainable development and intercultural dialogue through education, the sciences, culture, communication and information (en.unesco.org/about-us/introducing-unesco; Décamps et al. 2017).

“The principle of using education formal, non-formal and informal e as an effective vector to bring about change in values, attitudes and lifestyles to ensure a sustainable future for sustainability and, consequently, for sustainable development. The DESD strives to achieve these results through the following objectives: facilitating networking, linkages, exchange and interaction among stakeholders in ESD; fostering increased quality of teaching and learning in education for sustainable development; helping countries make progress towards and attain the Millennium Development Goals through ESD efforts; and provide countries with new opportunities to incorporate ESD into education reform efforts” (UNESCO, 2007).

The report written by UNESCO (2007) contains important concepts applicable to spreading knowledge towards sustainable development and obtaining results to implement objectives such as facilitating networking, linkages, exchange and interaction among stakeholders involved.

These objectives, together with the implementation of ESD in a common basis of knowledge and competencies, have been taken up by several member states, such as France[17], Finland[18], Japan[19] and UK[20].
Most of the initiatives carried out to transmit the concept of sustainable development should take place in educational contexts.
In 2012, the United Nations Conference on Sustainable Development (UNSCD), known also as Rio+20, changed the perception of the role higher education can, and should, play in the construction of a more sustainable world for next generations.
For the first time in the context of UN initiatives, the focus was put on the right to access to education and also on the responsibility of higher education (Décamps et al., 2017). This was to be a chance for students to translate intentions into implementation plans (Gollwitzer, 1999) specifically within the planning environment. They were to specify where, when, and how they would act and to develop specific plans to adopt when predictable difficulties arose (Arbuthnott, 2009).

4.2 ESD in Higher Education

Attention around the concept of sustainable development, SDGs and interlinkages has grown a lot in recent years. In particular, from the literature the need to educate people about these concepts has emerged. Education has become the key to trying to achieve a more aware and sustainable society for all (Foster, 2001).
This is the reason why raising the awareness of people developed into Education for Sustainable Development (ESD), a contemporary field deriving from Environmental Education (EE). This is defined in particular as a student-centered educational area that aims at motivating pupils and young people to become actively involved in the learning process for environmental and societal issues. The ESD is constantly seeking creative pedagogical approaches and methods that could attract and engage pupils and young people into its subject of study (Liarakou et al., 2012).
The ESD strives to change values, attitudes and lifestyles to ensure sustainability through these objectives:

i. To facilitate networking, linkages, exchange and interaction among stakeholders in ESD;

[17] http://www.eduscol.education.fr/numerique/dossier/archives/education-audeveloppement-durable-tice/place-education-audeveloppement-durable/textes-dereference
[18] http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/ED/pdf/esd2014/HL_round_table_Statement_Finland.pdf
[19] http://unesdoc.unesco.org/images/0014/001492/149295e.pdf
[20] http://www.esd.rgs.org/link9.html.

ii. To foster increased quality of teaching and learning in education for sustainable development;
iii. To help countries make progress towards sustainable development and
iv. to incorporate ESD into education reform efforts[21] (Carteron et al., 2014).

Providing quality education is a complex issue partially because the concept of quality in education is in a perpetual state of evolution (Laurie et al., 2016).
ESD programs should include social science courses to educate students on effective strategies for behavioural change. Specific actions with a focus on ESD could be integrated into exercises and assignments within courses, lessons and workshops. Educational programs that target specific domains (such as transportation, food and beverage, recycling, energy consumption, soil maintenance Abrahamse et al., 2007; Kempton, Darley and Stern, 1992; Guagnano, Stern and Dietz, 1995; Schultz and Stuart, 2010; Vining and Ebreo, 1992; Joireman, Van Lange and Van Vugt, 2004) will help students involved to frame more specific intentions in the relevant areas (Liarakou et al., 2012).
The role of universities becomes essential in the transformation process on sustainability (Miguel et al., 2020; Larrán, Andrades, and Herrera, 2018). Universities are the hubs where students learn and the use of new methodologies and ICTs can be actively implemented in classrooms (Miguel et al., 2020). Concerning educational activities, some studies (Petkov & Rogers, 2011) argue that educational systems need to incorporate the use of video games to accommodate the technology-dependent students of today (Liarakou et al., 2012). They are proficient at multitasking, they prefer visual information over textual, and are cross-media oriented since they are highly active on social network sites (Knol and De Vries, 2010).
Within the ESD process, the use of e-learning tools and serious games can help to implement SDGs knowledge in a more positive way (Miguel et al., 2020). Serious games are one of the fastest-growing areas in immersive educational media today (Bronack, 2011) because they aim at providing an engaging, self-reinforcing context to motivate and educate the players (Kankaanranta and Neittaanmaki, 2009). The players involved can develop several skills by playing, such as analytical and spatial skills, strategic skills and insight, learning and recollection capabilities, psychomotor skills and visual selective attention (Mitchell & Savill-Smith, 2004). The learning benefits of serious games make players feel responsible for success according to their actions, match high-quality content, turn mistakes into learning elements and solve problem-based learning (Protopsaltis et al., 2011).

[21] The UN Decade of Education for Sustainable Development (DESD 2005- 2014) The First Two Years. Paris, 2007.

Within the realms of ESD, serious games could play a critical role, as a pedagogical tool that gives young people opportunities to experience situations that are difficult to face in the real world in terms of safety, cost and time (Liarakou et al., 2012; Corti, 2006; Squire, 2002).

4.3 A new classification of serious games

One of the aims of this study is to construct a new classification of existing serious games that present connections with SDGs. This analysis was made focusing on the last decade (2007-2018), following up on two previous pieces of work carried out to classify serious games according to their sustainable development themes (Stanitsas et al., 2018; Ouariachi et al., 2018) and consulting three online database: Serious Game Classification, Games for Change and Games 4 Sustainability. In the Serious Game Classification online database, games are classified according to their gameplay, their purposes, their markets and target of users, alongside user-contributed keywords[22]. Games for Change is a community founded in 2004 to empower game creators and social innovators to drive real-world change using gamification methods and technologies. The final aim of Games for Change is to help people to learn new things by improving a sense of community and help make the world a better place to live in. Since it is a community, some activities were organized, such as the annual festival for serious games and student challenges or training students and educators to run game design [23] .Furthermore, Games4Sustainability is an online platform where users can learn and practice sustainability issues through serious game applications and find some links with the SDGs[24]. *Table 15* reports the most used tags/label in the literature and in the three online databases for describing the characteristics of games.

Table 15_ Description of tags and labels for serious games classification, according to the literature review and some online platforms

Tag/label	Description	References
Year	Release year	Stanitsas, Kirytopoulos and Vareilles (2019); gamesforchange.org; games4sustainability.org serious.gameclassification.com
Name of games	Proper name of the game	Werbach and Hunter (2012); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017);

[22] serious.gameclassification.com
[23] gamesforchange.org
[24] games4sustainability.org/gamepedia/

		Stanitsas, Kirytopoulos and Vareilles (2019); gamesforchange.org; games4sustainability.org serious.gameclassification.com
Type	App game, Board game, Online game, Pc game, Video game, Web	Werbach and Hunter (2012); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017); Stanitsas, Kirytopoulos and Vareilles (2019).
Genre	Adventure, Defense, Game based Management, Politic, Puzzle, Role playing game, Simulation, Strategy	Werbach and Hunter (2012); Katsaliaki and Mustafee (2015)
Platform	Personal Computer, Sony PlayStation 3, Nintendo Wii, Mobile Phone	Breuer and Bente (2010); Ratan and Rittefeld (2009)
Controls/interface	Gamepad controlled, mouse and keyboard, Wii balance board	Ratan and Rittefeld (2009); Breuer and Bente (2010); Madani, Pierce and Mirchi (2017)
Created by/Developer	The society's name that created and developed the games	Katsaliaki and Mustafee (2015); games4sustainability.org
Availability	How to get the game	Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017) serious.gameclassification.com
Target players/audience	High school children, nurses, students, general public, pre-schoolers, professors, military recruits	Ratan and Rittefeld (2009); Breuer and Bente (2010); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017); Stanitsas, Kirytopoulos and Vareilles (2019);
Numbers' players-interaction mode(s)	Multiplayer, Co-Tutoring, single player, massively multiplayer, tutoring agents	Ratan and Rittefeld (2009); Breuer and Bente (2010); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017)
Price	Sales price	gamesforchange.org; serious.gameclassification.com
Duration	Time spent to playing and finishing games	serious.gameclassification.com
Country	Nations that developed the games	serious.gameclassification.com
Language	Number and name of languages where games are available	games4sustainability.orgserious.gameclassification.com
Theme/topic	The subject matter within the games	Werbach and Hunter (2012); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017)

Game objective	Final goals to achieve at the end of the games	Werbach and Hunter (2012); Katsaliaki and Mustafee (2015); Madani, Pierce and Mirchi (2017)
Learning goals	Language skills, historical facts, environmental awareness	Ratan and Rittefeld (2009); Breuer and Bente (2010); Katsaliaki and Mustafee (2015)
Application area	Academic education, private use, professional training	Ratan and Rittefeld (2009); Breuer and Bente (2010); Stanitsas, Kirytopoulos and Vareilles (2019);
SDGs	Sustainable development goals	Agenda 2030 (2015); gamesforchange.org
Sustainable aspects involved	Sustainable actions, challenges and chances available in the games	Stanitsas, Kirytopoulos and Vareilles (2019); gamesforchange.org; games4sustainability.org
Awards	Number of prizes won in national or international competitions	serious.gameclassification.com
Publications	Number of publications, scientific articles or academic papers, published in scientific journals	serious.gameclassification.com
Entertainment level	How hard could it be engaging players	Werbach and Hunter (2012)

4.3.1 Method of research

The research method used to carry out this new classification is based mainly on 4 phases and summarized in *Figure 20*: 1) Finding the main serious games; 2) Filtering the main serious games; 3) Tracing the documents through a systematic literature review; 4) Synthesis and description (Cravero, 2020).

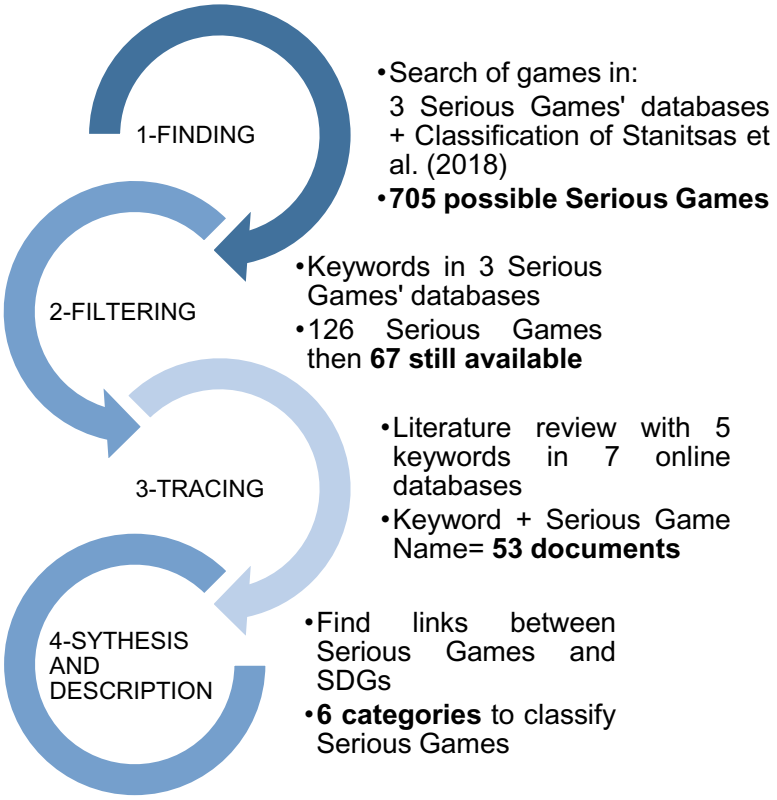

Figure 20_ Four main research phases (Cravero, 2020)

4.3.2 Finding phase

This phase is mainly characterised by the identification of the serious games to be analysed. As a first step, I decided to look at the three most used online serious games databases, introduced in the previous paragraph: Games4Sustainability (149 serious games), Games for Change (234 serious games) and Serious Games Classification (245 serious games) (Cravero, 2020). As a second step, I referred to the classification of the Serious Games proposed by Stanitsas et al. (2018) that listed 77 Serious Games between 1990 and 2018. This preliminary research brought 705 potential serious games to my attention

4.3.3 Filtering phase

The initial selection of 705 serious games was further reduced according to the main keywords that guided my research: “year (2007-2018)”, “city/cities”, “energy”, “climate”, “environment” and “SDGs”. It is important to emphasise that the above keywords are a compromise between the research topics and the possibly of filtering offered by the structures of the three serious games databases consulted. This analysis resulted in a list of 126 serious games, which was further decreased to 67 in order to consider the serious games currently in use. Moreover, during this

second filtering phase, I found that some of the 126 serious games were no longer available and therefore excluded them from the final list due to lack of data.

4.3.4 Tracing phase

Once the 67 serious games had been identified, it was necessary to review them in detail. This step was fundamental according to two main objectives: the first was to understand the educational purpose of each serious game; the second was to identify possible relationships between each serious game and the SDGs. Achieving this second objective proved to be complex, given that the SDGs were not officially established until 2015. Therefore, effort was needed to deduce the links between SDGs and the Serious Games implemented between 2007 and 2015. This third step of the analysis can be regarded as a literature review. As a matter of fact, neither Stanitsas et al. (2018) nor the three serious games databases reviewed provide an in-depth description of the 67 serious games. Therefore, I decided to search for information by conducting an in-depth literature review, consulting the 7 main scientific research databases available online: Scopus, Google Scholar, Web of Science, ResearchGate, SpringerLink, Sage Journal and Google books. The selection of these specific online databases was made because of the wide coverage of their papers (Cravero, 2020). In this exploration, the topic to be analysed in the 7 online databases is a combination of the name of the serious games and some specific keywords shown in *Table 16* below.

Table 16_ Selected keywords for the analysis (Cravero, 2020)

Serious Games	Keyword
Name of the 67 serious games identified in phase 2.	digital game-based learning (Ouariachi et al., 2018)
	educational games (Ouariachi et al., 2018)
	environmental games (Stanitsas et al., 2018)
	game-based learning (Stanitsas et al., 2018);
	serious games (Ouariachi et al., 2018; Stanitsas et al., 2018).

In accordance with *Table 16*, in each database I searched for the subject to be analysed, for example: “Energyville + digital game-based learning” or “Energyville + educational games”. This systematic literature review offered 53 documents including articles, books, abstracts and conference proceedings belonging to four main subject areas: engineering, computer science, social science and environmental science.

4.3.5 Synthesis and description of the analysis

By examining 53 documents detailing 67 Serious Games, I was better positioned to describe each serious game in depth and link them to the pertinent SDGs. In an effort to properly describe the themes of the games and relevant aspects of the problem, I described the 67 serious games using 7 categories (*Table 17*) based on the studies by Stanitsas et al. (2018) and the categories used by the 3 previously consulted serious games databases.
Stanitsas et al. (2018) provided the following categories: year, type, participants, teaching exclusivity and sustainable technology/sustainable development strategy. For this new classification I used four categories proposed by Stanitsas et al. (2018) and excluded the category "teaching exclusivity". The category "sustainable technology/sustainable development strategy" was called "SDGs" as it was more closely aligned with the purpose of my research. In addition, I identified two other categories from the three serious games databases: "Genre" and "Game Topic". These two categories were indeed instrumental in describing the aims and characters of serious games by highlighting the links between each game and SDGs. It is significant to remark that "Game Topics" under consideration in this analysis were deduced from the main SDGs goals in terms of sustainable development.

Table 17_ Selected categories for this new classification of serious games (Cravero, 2020)

Categories	Description	
Year	Timeline considered for the classification	From 2007 to 2018
Genre	Description of the way the game is developed	Adventure, Educational, Puzzle, Role-Playing Game (RPG), Simulation, Strategy
Type	Information about the tools and techniques used to play the game	App game, Boardgame, Card game, Hybrid Game, Online game, PC game, Policy exercises, Video game
Target	People directly involved in the games simply called players	Children, Youth, General public, Students
Game Theme	Description of the theme addressed within the game	Specific description for each game
Game Topic	Description of the main topics faced by the games analyzed based on the main sustainability concepts.	Climate change, Energy management, Inclusive access to justice, Sustainable actions for the environment, Sustainable resource use,
SDGs	The link among the games analyzed and the 17 SDGs identified in the Agenda 2030.	From 1 to 17

In the following page *Table 18* shows the 67 Serious Games described according to the appropriate identified categories.

Table 18_ Ranked serious games classified by 7 categories (2007-2018) (Cravero, 2020).

Year	*Serious Game Name*	*Genre*	*Type*	*Target*	*Game Theme*	*Game Topic*	*SDGs*
2007	**Climate Challenge (BBC)**	Strategy	Online and PC game	General public	Climate challenge, carbon dioxide emission	Climate change	13
	Electro city	Strategy	Online game	Students	Energy and environmental management	Energy management	7, 11
	Energyville	Strategy	Online game	Students	Energy and environmental management	Energy management	7, 11
	Food Import Folly	Educational, Simulation	Online game	General public	Quality food imports	Sustainable resource use	2, 4
	PeaceMaker	Puzzle	Video game	General public	Created to simulate the peace-making process in the Middle East.	Inclusive access to justice	16, 17
	Stop disasters	Simulation, Strategy	Online game	Children, Youth	Methods of prevention and mitigation.	Climate change	12, 13
	World without oil	RPG	Online game	General public	Oil environment risk	Sustainable actions for the environment	15
2008	**Catchment detox**	Strategy	Online game	Children, Youth	Managing a river catchment and creating a sustainable economy.	Water cleaning and management	6, 12
	Global Conflicts: Latin America	Adventure	Online game	Students	Environmental problems	Sustainable immigration and cultural integration	1, 3, 10
	Heifer Village: Nepal	Simulation	Online game	General public	Environmental management	Sustainable immigration and cultural integration	1, 2, 3
	Wild web woods	Educational	Online game	Children, Youth	Sustainable development	Inclusive access to justice	4, 16
2009	**City Rain: building sustainability**	Simulation	Online and PC game	General public	Green city simulation puzzle	Sustainable actions for the environment	11, 12

	Serious Game Name	*Genre*	*Type*	*Target*	*Game theme*	*Game topic*	*SDGs*
	MIT CleanStart	Simulation	Online and PC game	General public	Green urban management	Sustainable actions for the environment	7, 8, 9, 12
	PowerUp	Educational	Online game	Students	Fossil fuels and renewable energy	Energy management	4, 7
	SOS 21	Simulation	Online game	General public	Broadcast ecologic messages.	Energy management	7
2010	**Cityone**	Simulation	Online and PC game	Students	Urban and sustainable planning	Sustainable urban development	11, 13
	Energy City	Educational	Online and PC game	Students	Energy-saving and environmental awareness	Energy management	4, 7, 11, 12, 13
	The fate of the world	Strategy	Online game	Students	Impacts of climate change, population growth, resource over-exploitation	Climate change	8, 13
	Green my place	Educational	Online game	General public	Player's behaviour towards energy saving issue	Energy management	7, 11, 12
	Sustainable Delta	Simulation, Strategy	Hybrid game	General public	Water system and management	Water cleaning and management	6
	The UVA Bay Game	Educational, Simulation	Video game	Students	Reclaimed water management	Water cleaning and management	6
2011	**Citizen Science**	Adventure	Online game	Students	Water and pollution issue	Water cleaning and management	6
	River Basin Game	RPG	PC game	Students	Water management in agriculture	Water cleaning and management	2, 6, 12
	Spent	Simulation	Online game	General public	Poverty and homelessness	Sustainable immigration and cultural integration	1, 2, 3, 4
2012	**Aqua Republica**	Simulation, Strategy	Online game	Students	Managing limited natural resources	Sustainable urban development	6, 12, 13, 14
	Earthopoly	Educational, Environment	Board game	Students	Take care for the earth and protect our precious resources	Sustainable urban development	4, 12

	Serious Game Name	*Genre*	*Type*	*Target*	*Game Theme*	*Game Topic*	*SDGs*
	EconoU	Simulation, Strategy	PC game	General public	Sustain a fictional University to economic sustainability.	Sustainable urban development	11, 12
	Irrigania	Simulation, Strategy	Online game	Students	Water conflicts among farmers in a simplified way	Water cleaning and management	6
2013	**Climate change Survivor**	Simulation	Board game	General public	Climate change impacts	Climate change	13
	Climate Defense	Educational	App game	General public	Preventing global warming	Climate change	7, 12, 13
	Energy2020	Educational	Online game	General public	Climate-based disaster risk reduction	Climate change	4, 13
	Pipe Trouble	Puzzle	Online game	General public	Real-world issues surrounding the exploitation of natural gas.	Sustainable urban development	11
	Plan It Green: the big switch	Educational, Simulation	Online game	Children, Youth	Design and create your own energy-efficient city of the future.	Sustainable urban development	7, 11
	World climate	Simulation	PC game	General public	Decisions affect the global climate system	Climate change	13, 17
2014	**About that Forest**	RPG	Video game	General public	Earth resources management	Sustainable actions for the environment	10, 11, 12, 15
	Ciclania	Educational, Environment	Online game	General public	Environmental issues	Sustainable actions for the environment	6, 7, 13
	Les maîtres de l'eau	Educational, Environment	Video game	General public	Water management and urban planning	Water cleaning and management	6
	Never Alone	Puzzle	Video game	General public	Resource management	Sustainable actions for the environment	12
2015	**Cities: Skylines**	Simulation, Strategy	Video game	General public	Government's role in social sustainability	Sustainable actions for the environment	11, 12, 13, 16
	Earth: A Primer	Simulation	App game	General public	Food sustainability & geopolitics	Sustainable resource use	15
	EcoChains: Arctic Crisis	Educational, Simulation	Card game	General public	Food chains and protect Arctic animals	Sustainable resource use	13, 14, 15

	Serious Game Name	Genre	Type	Target	Game Theme	Game Topic	SDGs
	Evacuation Challenge Game	RPG	Policy exercises	General public	Disaster response and evacuation during the disaster.	Sustainable urban development	5, 11
	Extreme Event: Coastal City	RPG	Policy exercises	General public	Sustainable urbanism	Sustainable urban development	11
	Polar Eclipse	Educational	Board game	General public	Climate change and climate risk	Climate change	13, 14, 15
	The Arcade Wire: Oil God	RPG, Strategy	PC game	General public	Fluctuations in gasoline prices.	Sustainable resource use	12
2016	**2030 SDGs Game**	Simulation	Card game	General public	Taking the "real world" into the year 2030.	Sustainable development for the environment	All
	Flood Resilience game	RPG	Board game	General public	Flood, Flood Resilience	Sustainable actions for the environment	6, 9, 11, 12, 16
	Laudato Si	Simulation	Board game	General public	Religious education	Inclusive access to justice	1, 10, 12, 13, 15
	Lie, Cheat & Steal	Simulation	Board game	General public	Politics of sustainability	Inclusive access to justice	16
	Minecraft: Education edition	Educational, Simulation	PC game	Students	Learning in traditional classroom environments.	Cultural integration	4
	Urban Climate Architect	Simulation	Online game	General public	Water management for SD	Water cleaning and management	11, 12, 13
2017	**Energy transition game**	RPG	Policy exercises	General public	Energy transition, renewable sources	Sustainable resource use	7, 8, 9, 13, 15, 16
	Flood control game	Simulation	Board game	General public	Flood disaster management	Sustainable actions for the environment	6, 16
	Gifts of culture	RPG	Board game	General public	Flood resilience	Sustainable actions for the environment	3, 4, 6, 10, 11, 15
	Gogoals	Educational	Board game	Children, Youth	Sustainable development goals	Sustainable development for the environment	All
	Lords of the valley	Simulation	App game	Students	Practicing strategy, collaboration, and leadership in a complex environment	Sustainable actions for the environment	6, 8, 10, 11, 14, 16

	Serious Game Name	*Genre*	*Type*	*Target*	*Game Theme*	*Game Topic*	*SDGs*
	New shores: a game for democracy	Simulation	PC game	General public	Climate change in the context of democracy.	Sustainable actions for the environment	8, 10, 11, 12, 13, 14, 16
	Nexus	Simulation, Strategy	Board game	General public	Sustainable civilization	Sustainable actions for the environment	2, 6, 7, 12, 17
	The Catan: oil sprigs scenario	Simulation	Board game	General public	Environment. Pollution.	Sustainable resource use	6, 7, 9, 12, 14, 15
	The world's future	RPG	Board game	General public	Heritage urbanism	Sustainable development for the environment	All
2018	**Co-construisez, qu'il disait**	Educational	Board game	General public	City planning	Sustainable urban development	11
	ECO	Strategy	Video game	Students	Participation in town planning	Sustainable actions for the environment	6, 12, 15
	Il était ANRU'ne fois	Educational, simulation	Card game	General public	Relationships in smart communities	Sustainable urban development	11
	Interactive Board Game (SIG)	Educational	Board game	General public	Implementation of SDGs	Sustainable development for the environment	All
	La fabrique des territoires durables	Educational, simulation	Board game	General public	Development and management of sustainable cities	Sustainable urban development	8,11, 12
	Paris 1800	RPG	Board game	General public	Urban transformations with historical references	Sustainable urban development	8, 11, 12
	Unda	Educational	Board game	General public	Management of sustainable cities	Sustainable urban development	11

4.3.6 Outcomes and discussion

The outcomes of this new classification of sustainability serious games for SDGs are manifold. In order to better integrate the results obtained, a variety of graphs are illustrated and explained over the following pages.

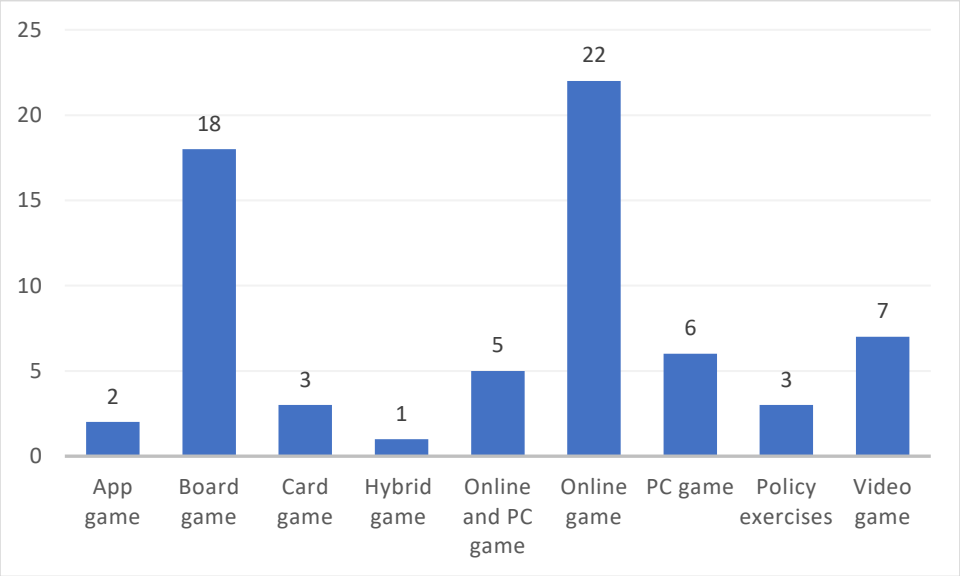

Figure 21_ Serious games' type (Cravero, 2020)

Figure 21 shows that most parts of games are online (22), followed by board games (18) and PC/video game type (7). The outcome is not surprising, given the current trend of society to live "online"; what is less predictable is the importance that board games still have. Additional considerations regard genres, by looking at the outcomes in *Figure 22*. According to their use, six main genres are identified: simulation (24), educational (21), RPG (11), strategy (6), puzzle (3) and finally adventure (2). Close scrutiny of the graph shows that serious games can be developed following one or two genres. This is because genres can be complementary and not exclusive. For instance, serious games can be both simulation and strategy at the same time, such as Nexus, or both educational simulation like Minecraft: Education edition, or both RPG and strategy as The Arcade Wire: Oil God. According to this, it emerged from the classification that certain gender juxtapositions are common in games such as for simulation, educational and RPG. The outcomes are respectively:

- 24 simulations, 7 of which are also strategy;
- 21 educational, 7 of which are also simulation, 3 of which are educational and environmental, 1 is also RPG;
- 10 RPG, 1 of which is RPG and strategy.

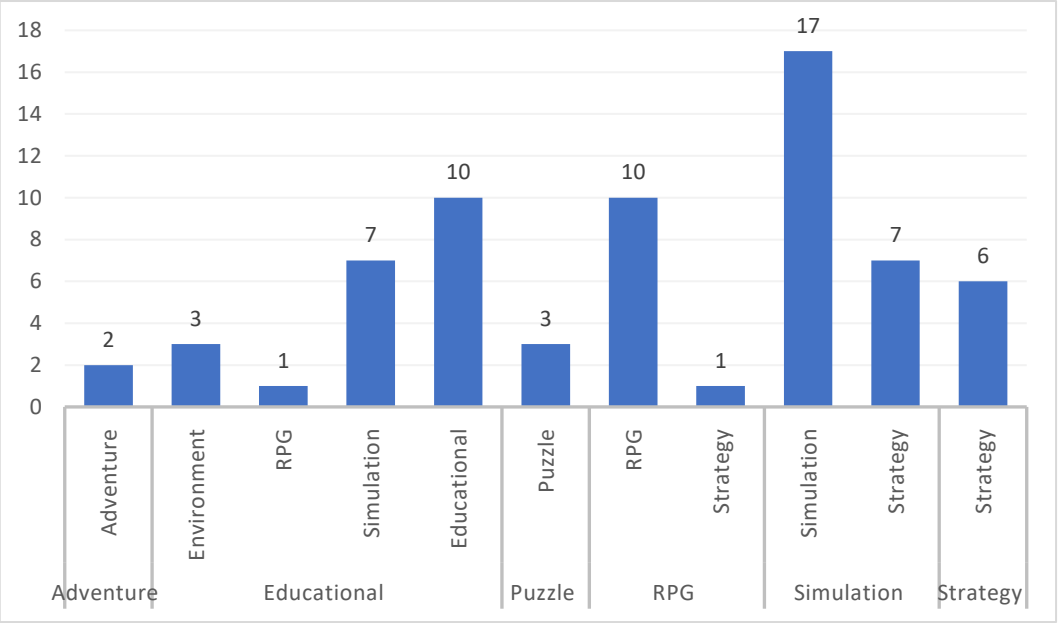

Figure 22_ Different genres of serious games (Cravero, 2020)

A good combination of two genres can generate more interesting and immersive serious games, by working on the players' level of engagement. An important factor to note is that these games work simultaneously on both learning and fun aspects, so the approach of basing play on two genres can contribute to maintaining the attention of the players (Cravero, 2020).

The analysis of results continues, looking at the category called target. The distinction made between the categories of users at which serious games are aimed is based on the intended use of the games. Serious games that have been created specifically for children and young people are labelled as "children, youth". On the other hand, as regards games such as Citizen Science, Irrigania or Minecraft: Education edition, designed specifically for schools (of different order and level), the target audience identified is "students". Serious games aimed instead at a wider audience without distinction of age, gender and educational purposes were labelled as "general public" (games4sustainability.org; gamesforchange.org; serious.gameclassification.com). Accordingly, *Figure 23* shows that the majority of classified serious games are aimed at the general public (46), followed by students (16) and children and youth (5).

This means that most of the serious games had been created for everyone and not for a specific catchment area of people. It is not always necessary to have very specific knowledge in terms of sustainability, allowing all those interested in sustainable educational serious games to play. This corresponds to one of the main characteristics of serious games, being available and accessible to all ages and population groups (Mouaheb et al., 2012).

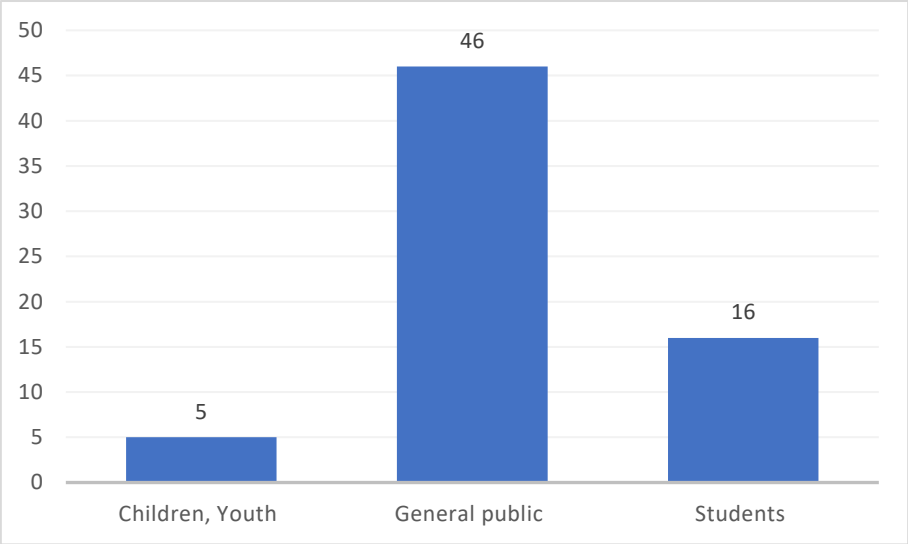

Figure 23_ Serious games' target (Cravero, 2020)

Regarding the topics of games, *Figure 24* shows some outcomes of ranked games. Each serious game tackles a specific topic of sustainability. The Game Topics are summarized in 10 main groups according to three online databases consulted (games4sustainability.org; gamesforchange.org; serious.gameclassification.com). Those are respectively:

- Climate change
- Cultural integration
- Energy management
- Inclusive access to justice
- Sustainable actions for the environment
- Sustainable development for the environment
- Sustainable immigration and cultural integration
- Sustainable resource use
- Sustainable urban development
- Water cleaning and management

Most of the classified serious games are ranked in the topic of "Sustainable actions for the environment" (14), followed by "Sustainable urban development" (11), "Climate change" (8) and "Water cleaning and management" (8). These findings can be interpreted as a desire to make these games as engaging, and therefore as "educational" as possible, towards urban and sustainable challenges. Poplin (2012) stated that those games offer immersive interactions for players through the creation of virtual worlds with interesting and involving features such as interactive stories, fascinating challenges and clear goal structures for problem solving.

Other studies confirm that common features of all intrinsically inspiring environments include challenges, chance, control and fantasy to capture attention and pique curiosity in people involved (Lepper and Malone, 1987; Malone, 1981; Reiber, 1996). Tendentially, the main strengths of serious games may belong to the areas of communication, the visual expression of information, collaboration

mechanics and finally interactivity and entertainment (Anderson et al., 2009; Salen and Zimmerman, 2004). All these features characterise serious games regardless of their genre, topic or participants, because examples include games used in military contexts and training, health care, cultural heritage, urban planning and public participation (Krek, 2008; Poplin, 2011).

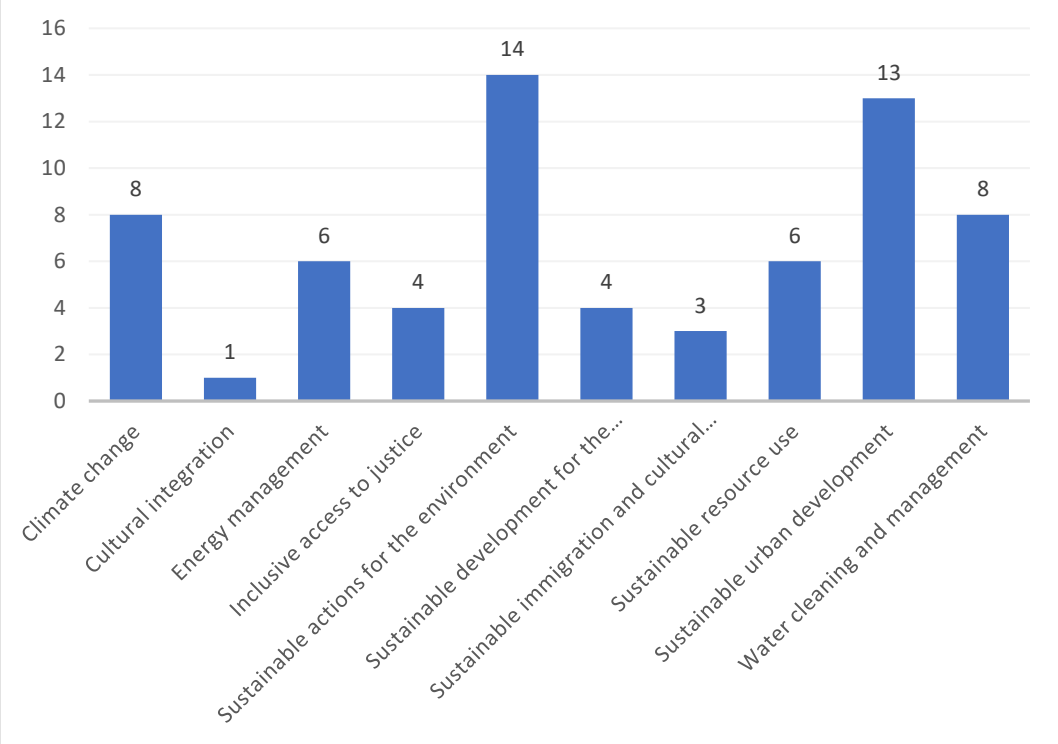

Figure 24_ Serious games' topic (Cravero, 2020)

From a sustainability point of view, these serious games reflect important calls established by Agenda 2030 in terms of future development for every country around the world (Cravero, 2020). Topics such as sustainable actions or sustainable development, climate change, sustainable resource use or energy management are issues that smart cities have to tackle on every day, to guarantee development for future generations. In this regard, the last considerations about this new classification concern the relation between serious games topics and 17 SDGs, as shown in *Figure 25* and *Figure **26***.

Figure 25 shows the results of the analysis of serious games developed between 2007 and 2014. In particular, this graph displays how many and which SDGs are addressed for each classified serious game.

Through the searches conducted on the three online databases about the characteristics and the available information of these games, I was able to identify which SDGs were dealt with in the newly classified games. The information collected from Serious Game Classification, Games for Change and particularly Games 4 Sustainability helped me in the correct identification and attribution of the SDGs.

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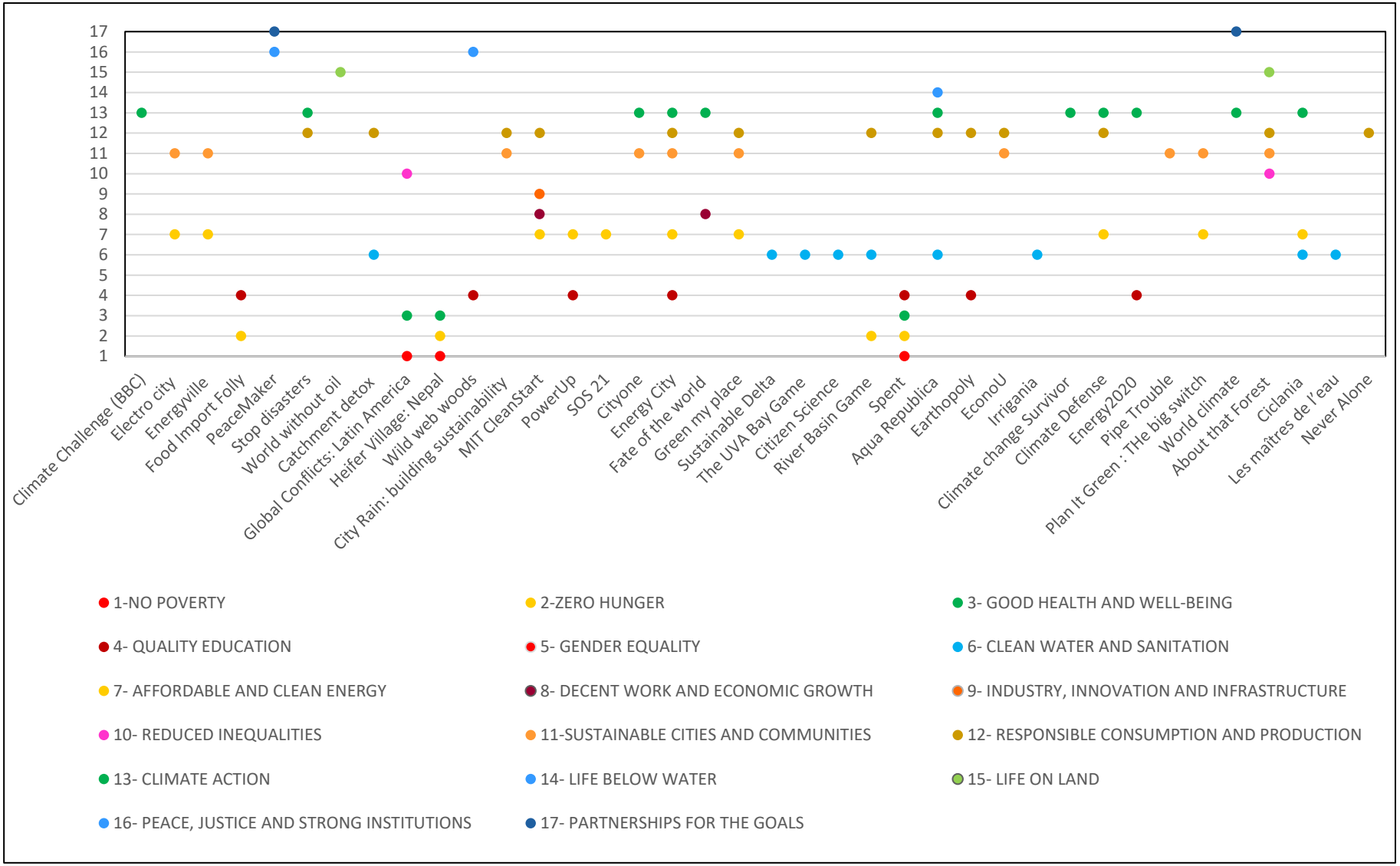

Figure 25_ Serious games (2007-2014) classified according to covered SDGs (Cravero, 2020)

The outcomes demonstrate that most of SDGs covered relate to SDG12- Responsible consumption and production (13), followed by SDG13- Climate actions (11) and finally by SDG11- Sustainable cities and communities (10) and SDG7- Affordable and clean energy (10) (Cravero, 2020). These numbers show that reference to SDGs in serious games up until 2015 already existed. This may prove that even before the establishment of the SDGs by UN member states, the consideration of sustainable issues was already being recognised. *Figure **26*** provides further detail on the results of the analysis of serious games developed between 2015 and 2018, after the establishment of SDGs.

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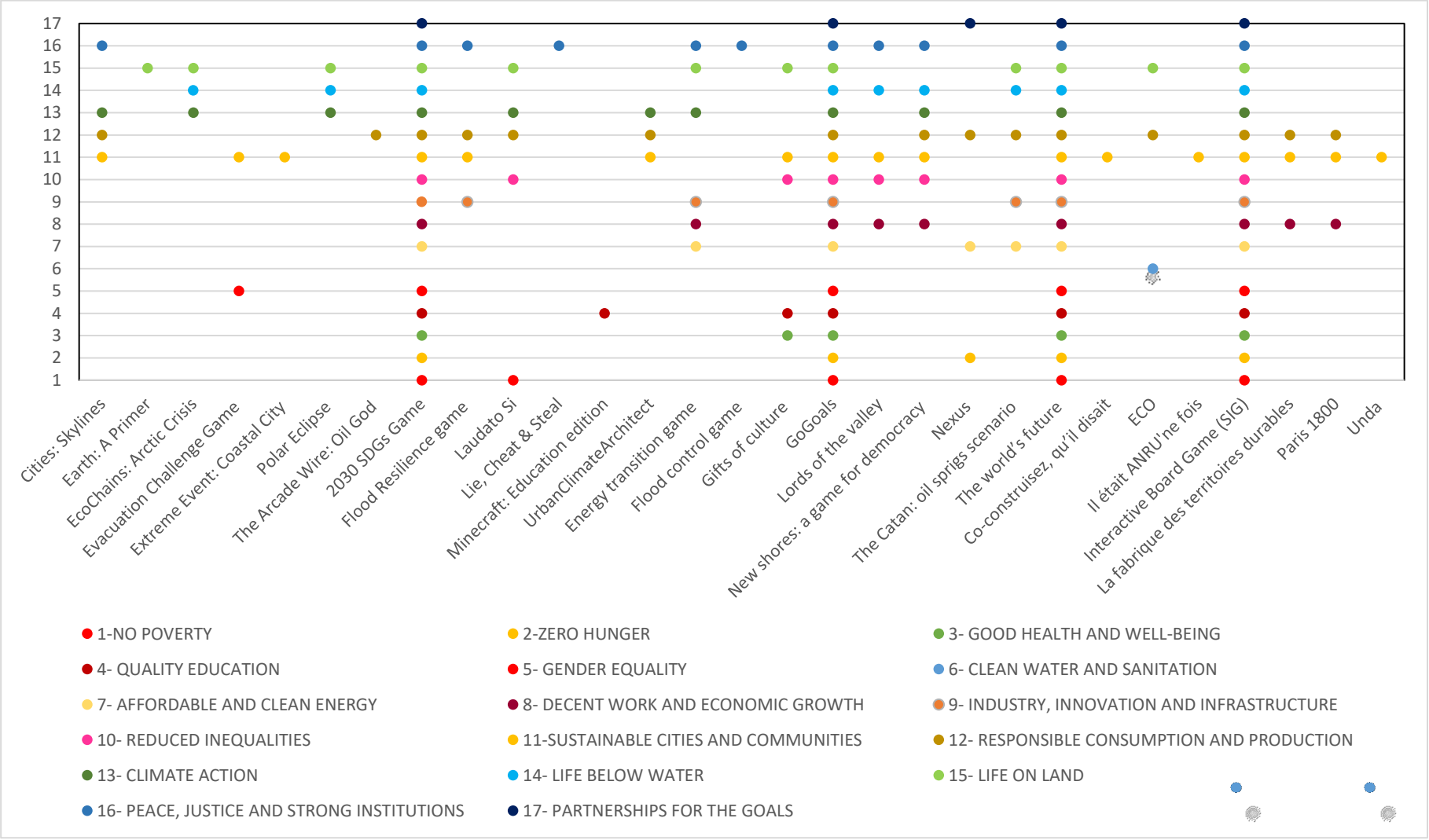

Figure 26_ Serious games (2015-2018) classified according to covered SDGs (Cravero, 2020).

The outcomes show that most serious games analysed are related to the SDG 11- Sustainable cities and communities (17) followed by SDG 12- Responsible consumption and production (15) and SDG 15- Life on land (12). The general results of this new classification thus show that the SDGs most frequently addressed in games are as follows:

- SDG 12 in 28 serious games;
- SDG 11 in 27 serious games;
- SDG 15 in 12 serious games;
- SDG 13 in 11 serious games;
- SDG 7 in 10 serious games.

SDG 12 is the most frequently covered goal in the 67 serious games analysed. It was addressed in 41% of cases. Afterwards, SDG 11 with 27 applications was tackled in 40% serious games. The other goals, on the other hand, were addressed significantly less often, 1.7% for SDG 15, 1.6% for SDG 13 and 1.4% for SDG 7, respectively. In addition, 70% of serious games deal with many goals at the same time and specifically 27% of these deal with both SDG 11 and SDG 12 while 25% deal with SDG12 and SDG 13.

These outcomes show that the largest number of serious games covered SDG 12 followed by SDG 11. Issues concerning sustainable development, both in terms of consumption and production and of sustainable cities and communities, are also addressed rather a lot in serious games. One of the consequent questions that arises on the subject of SDGs is how they are actually dealt with within the games.

Chapter 5

Talenti Polito Challenge

This chapter is dedicated to the experience of the Talenti Polito Challenge and the subsequent application of the analytical flow chart. The challenge in question was an internal competition involving 59 students of Politecnico di Torino who took part of "The Path for Emerging Talents". The aim of this challenge was to develop serious games for a more sustainable campus of Politecnico di Torino. The games produced had to take into account at least two of the SDGs.

The sections below describe Talenti Polito Challenge according to its organization, the games developed and their assessment. This last part is structured according to two perspectives. The first one concerns the outcomes of the challenge obtained in terms of serious games produced, analysing their quality and characteristics. The second standpoint, on the other hand, focuses on the challenge as a real formative learning experience through the design and development of new serious games. Both outcomes were analysed through appropriate questionnaires from both qualitative and quantitative perspectives. In particular, through a post-experience questionnaire and structured interviews, it was possible to qualitatively assess the students' experience. Through those questionnaires I answer the specific research question introduced in Chapter 1: *In the contest of Education for Sustainable Development, is Talenti Polito Challenge a compelling and effective novel approach to be adopted compared to more traditional methodologies?* Results show that

students positively assessed the learning effect and their improved teamwork abilities solicited by the activity.

5.1 Presentation of Talenti Polito Challenge

From academic year 2014/15, the Politecnico di Torino started an educational program known as “The Path for Emerging Talents” aimed at developing the potentials of promising students. This program is aimed at 200 engineering and 40 architecture bachelor students selected for specific requirements of merit.
Moreover, since academic year 2019/2020, The Path for Emerging Talents has become a field of experimentation for innovative educational initiatives which provide specific insights into advanced curricular subjects and promote ad hoc activities that will complement traditional study plans.
In the academic year, 2019/2020 one of these educational initiatives has been envisioned in the “Challenge Talenti- Promoting the sustainability of university campuses through serious games”, coordinated by the scientific responsible Professor Lami, in which students were asked to develop a serious game prototype focused on raising awareness on sustainability-related themes within the Campus of Politecnico di Torino. Serious games are considered valuable tools for ESD. They can raise sustainability awareness, solicit changes in players’ environmental behaviour and facilitate the comprehension of SDGs. In this regard, the premise of the challenge is that the role of students, as developers of a serious game, would enable them to become active participants in the overarching learning activity. In the end, the expected outcome is to make participants more aware of sustainability themes through an applied/playful approach. Furthermore, students will have acquired game design skills and, more in general, a global vision of the process behind the development and management of a product designed for the end-user.

5.2 Organization

The Challenge took place from March 10th to June 12th, 2020. During this period students were required to attend teaching activities delivered by university professors and tutoring sessions guided by a team of four tutors, composed of industry professionals and Ph.D. students. In addition, I personally contributed to the challenge by providing teaching materials, preparing lessons, participating in reviews with the tutors and, above all, producing the final evaluation questionnaires.
For the Challenge, 59 students took part in the “The Path for Emerging Talents” program, selected from nearly all the engineering Bachelors programmes taught at Politecnico di Torino. Students were divided into eight teams and to ensure heterogeneity, the teams’ composition was based on information gathered from a questionnaire submitted a couple of weeks before the launch of the challenge.

Participants were asked to self-evaluate their technical and practical skills related to areas of expertise (e.g., programming, modelling and graphics, game knowledge, economy and resource management), useful to realize the final product. The questionnaire and the data processing were managed by two members of the tutoring team who are also founders of the consulting agency DEM Future[25], a young and creative team involved in cutting-edge software development, design, and consulting projects. The Challenge was divided into three main phases organized as shown in *Figure 27* and described as follows:

- Preparatory and Design: this phase was primarily composed of lectures on a variety of topics mainly aimed at providing students with all the basic knowledge required to develop a serious game based on sustainability themes. Students were then asked to brainstorm their ideas producing the design of a concept for the serious game.
- Development: based on the designed concept, students focused on the development of a minimum viable product (MVP) of the serious game.
- Playtesting and Finalization, based on feedback received from the MVP evaluation and through a series of playtesting sessions, students modified their serious game reaching a final prototype which was evaluated by the teaching professors and tutors (Cravero et al., 2021).

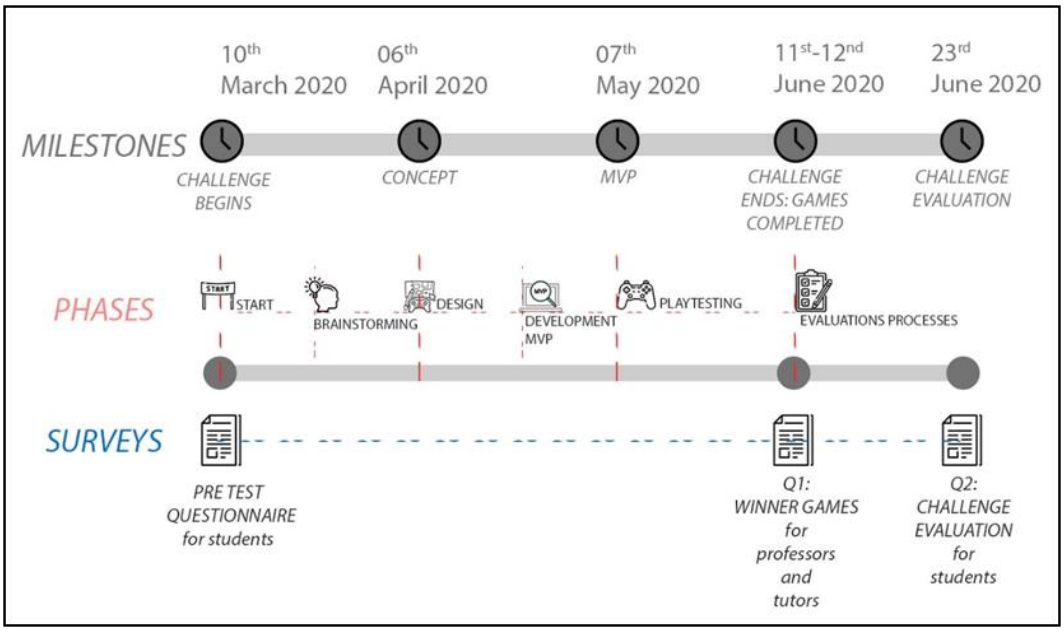

Figure 27_ Timeline of the main processes of the challenge

Each phase ended up with the submission of specific assignments, assessed by the professors, aimed at monitoring the teams' progress. In-phase advancements were

[25] https://demfuture.com/

tracked and controlled by tutors through a set of weekly daylong sessions. All activities, such as lessons, intermediate deadlines, review of the tutors, game developing and game sessions, should have taken place in person in the university spaces (e.g., classes, study rooms). However, due to the Coronavirus pandemic, the entire program of the Challenge was readapted entirely, and all the activities were rescheduled to be carried out entirely through online platforms such as Zoom, Skype, Teams, Discord and Big Blue Button.

The initial step during the Preparatory phase was the introduction to the Challenge and the presentation of the requirements the final serious games were to satisfy:

- Digital, physical (tabletop), or hybrid final game type
- Single-player or multiplayer (from 3 to 8)
- Game sessions lasting up to 30 minutes
- Focused on at least 2 of the SDGs
- Interlinkages between SDGs should be investigated
- Set within the Politecnico environment (Cravero et al., 2021).

Also, during the first day, the students were asked to collaboratively play Fate of the World, a 2011 global warming game, where players are in charge of a fictional international organization and are required to manage social, technological and environmental policies. This playing session was primarily envisioned as a team-building activity, allowing students to meet and interact with the different team members (students did not know each other before the Challenge). Besides, this helped professors and tutors identify any critical issues within the groups. The playing session also served as an introduction to the first game design and game development lectures, which went into further detail throughout the following weeks. In these initial weeks three other relevant classes were held relating to evaluation and sustainability, the launch of new products and sustainability energy aspects. The remaining weeks of the first phase were scheduled as brainstorming and design sessions coordinated by the tutors, who guided and helped teams in the creation of a game concept. The outcome of this process was then presented to the professors' committee on April 06th. Each team was asked to deliver a 15-minute presentation, and clarify any eventual doubts or issues highlighted by the professors.

Throughout the second phase (Development) students mainly focused on the development of the second assignment, the MVP scheduled for May 07th. This consisted in the creation of a working game prototype inclusive of the main mechanics, media and technologies used onto which all the secondary aspects would subsequently be integrated: these included graphics, leader boards, prints, design strategies, production, distribution, product marketing communication. Students had already completed all the lectures in the previous phase, and during

this second one, they mainly met with the tutors, who helped adjust and refine their MVPs.

Once professors had assessed the MVPs, students started the final phase (Playtesting and Finalization), which focused on the improvement of the prototypes. Based on the feedback received throughout different playtesting sessions, organized privately and carried out with the tutors, students were able to refine and improve their prototypes for final delivery. Moreover, thanks to my Ph.D. research collaboration with the ETH Game Technology Center (GTC), we organized an extra meeting for an intermediate review of the serious games, before the final delivery. This meeting, also held online, was very profitable since GTC provides an umbrella over ETH research, teaching, and outreach in the area of game technology working on different disciplines such as learning, citizen science, and human behaviour. The final step of this phase was the definition of a simplified "Production Plan", with the objective of making students reflect on the resources required to finalize their prototype and make it into a commercial product.

The final delivery was organized as a two-day activity. On June 11th 2020, a group of four professors and a group of tutors played each serious game for at least 45 minutes. At the end of each play session, they were asked to fill in an evaluation questionnaire (Q1: Professors and tutors' questionnaire) aimed at assessing the games' fulfilment of requirements and the overall playability. Beyond the gaming experience, this evaluation also took into account a system of bonus and malus, defined at the beginning of the Challenge, and linked to some educational aspects (e.g., number of SDGs used correctly). On June 12th 2020 each team performed an online presentation of the serious games developed. In addition to the professors' committee, this presentation was open to the Green Team, a group internal to Politecnico di Torino in charge of defining and promoting sustainable practises for the campus. We collected audience's votes, on a scale from 1 to 5, for each serious game presented. Combining these with the evaluation from the previously described questionnaire, we prepared a final leader board of the teams.

It must be noted that before the pandemic situation erupted the final presentation was imagined in a completely different fashion. Teams would have created a physical exhibition composed of stands equipped with gaming stations for visitors (students of the university, members of the other teams, teachers/tutors) who would have been able to test the various developed serious games. The visitors would have been equipped with an evaluation card through which they could evaluate at least two games.

5.3 The serious games developed

The 59 students involved in the Talenti Polito Challenge developed 8 serious games, 7 of which are table games and 1 is an app for smartphones. The winners of the challenge were 4. First place went to "Patent" (group 1), "Polinks" (group 7) was the runner-up while "iPolito" (group 4) and "4…3…2…1…Sustainability" (group 6) took third place. "Polistoria" was the only game developed as an app for smartphones and this is the reason why received the award of "daring technology" for the extra effort demonstrated. Due to the pandemic crisis of Covid-19, all the games were developed on Tabletopia, a multimedia platform where it is possible to design and realize games. In the following, the 8 serious games developed by the students who took part in the Challenge are described, according to the initial request to incorporate at least 2 of the 17 SDGs and set the game within the campus.

1. **Patent**[26] is the game-winner developed by group 1. In Patent, players have to make choices on technology development and investment in human resources aiming at a more sustainable university campus. This serious game encourages cooperation and collaboration among the main characters of the sustainable transition. The main goal is obtaining as many sustainable points as possible faster than other players by the end of the game. The game is composed of a dashboard, coin stickers, sustainable stickers, human pieces, "technology cards", "action cards", "department cards" and one companion app able to generate unforeseen events. At the beginning of the game, every single player chooses a card randomly from the "department pack" and receives a specific number of human resources, coin stickers and "technology cards" as identified on the top of the card. At this time the player organizes his human resources in the working area to do activities such as research, teaching, consultation and creation of projects. During each round, the players have to decide how to invest the available human resources and the coin stickers to improve them round after round. Some additional special rules, such as synergies and exchanges, increase the level of engagement and interactions during the game sessions. As shown in *Figure 28*, synergies are created between two "technology cards" according to their actions by generating 2 sustainability extra points. If a player gets 3 technology cards with the same colour, he obtains 1 more extra point and 2 if he gets 5 cards of technology. Exchanges of coins, technologies and human resources are allowed among the players. The game can end in 3 different ways establishing a limited number of rounds, a limited time for play (around 50

[26] Developers: Branda Edoardo, Carraria Martinotti Ludovico, D'amico Alessandro, Mercogliano Paolo, Nurisso Marco, Peluffo Simone, Saletti Giacomo

minutes), or obtaining the number of sustainability points defined at the beginning of the match

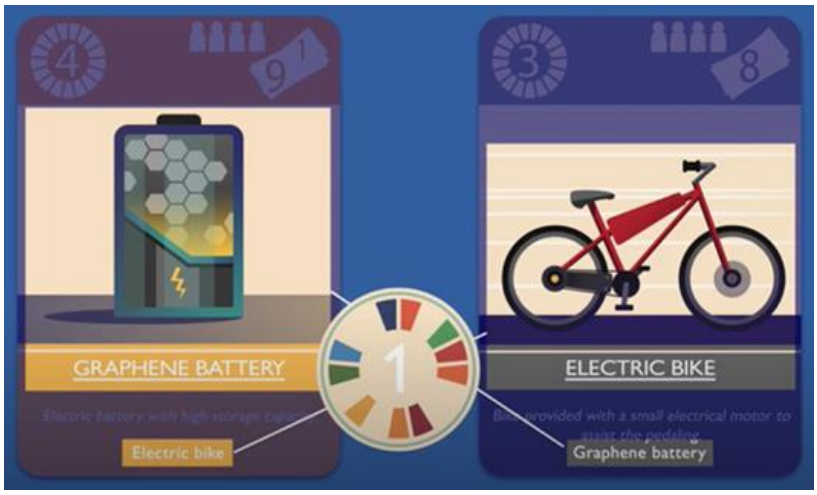

Figure 28_ Example of possible synergies between 2 technology cards designed in Patent

2. **Polirenewal**[27] is a serious game set in 2025 where the Rector of Politecnico di Torino has bought 4 abandoned buildings to enhance the number of classrooms, laboratories and environmentally friendly solutions.
   Designed by group 2, in Polirenewal 4 students are in charge of directing redevelopment works. Each of the works is divided into 5 main steps of environmental improvement and all players have to realize their project in order to finish the game. Polirenewal addresses SDG7-Clean Energy, SDG11-Sustainable Cities and Communities and SDG12-Responsible Consumption and Production. According to the sustainable actions taken within the game, the players obtain sustainability points.
   All the interventions and architectural elements of the game are based on real solutions, more or less innovative or eco-friendly. The challenges that characterize Polirenewal stimulate the player to think in terms of sustainability. The player that obtained the highest number of sustainability points, at the end of the game, wins. Polirenewal is designed for young people between 20 and 30 years old, preferably university students and PhD students that like games and have interests in technologies and construction. Although there is an ideal user in mind for Polirenewal, the game is potentially aimed at anyone. Given the young age of the potential public, the

[27] Developers: Bari Andrea, Cena Carlo, Cibrario Luca, Fenoglio Dario, Morandi Giorgia, Raviola Matteo, Valandro Antonio

media are entirely developed through social channels, including Instagram. The game's social page aims to advertise the product before launch, build a community and update the followers in case of expansions or other events. Despite the pandemic situation Polirenewal was designed as a table game. The game box is compact and space-saving, with appropriate slots for each component. The box and its contents are made of cardboard except for the internal support, which instead comes from recycled plastic. The contents of the box are the result of the intention to minimize the use of materials, remaining faithful to the sustainability theme (*Figure 29*).

Figure 29_ Example of a possible game session of Polirenewal among 4 players

3. **Polistoria**[28] is designed by Group 3 and is the only serious game of the challenge realized as an app for smartphones. The basic idea behind Polistoria is to tell a story through a text adventure game as in "Lapse: a forgotten future". Within this game are tackled SDG7-Clean Energy and SDG12-Responsible Consumption and Production. The game starts when the player chooses a character of the story, between student and rector. These two profiles are both measured through 4 indicators. The student's profile is characterized by waste, renewable resources, culture and recreation indicators. The rector's profile is measured differently through the welfare of the university and its budget instead of culture and recreation indicators. In both cases, the player has to make several daily choices for an entire week spent at the campus. As a student, for instance, the player may choose between his own lunch box or sandwich bought at the bar, get to the university by driving a car, by riding a bicycle, or by walking. Every choice has its own weight. Due to the actions taken during the game, the player receives more or fewer points according to the respective indicators (*Figure*

[28] Developers: Castronovo Alberto, Dordoni Luca, Fassino Davide, Robbio Marco, Rossi Luca Francesco, Savant Aira Luca, Tortoriello Valentina

30). The player has the task of keeping the score of all the indicators as high as possible until the game is over. The game ends when the player completes an entire week of activities at Politecnico di Torino by receiving a final evaluation according to actions taken.

Figure 30_ Screen of possible choices to be taken in Polistoria according to student mode

4. **iPolito**[29] is a competitive card game developed by Group 4 that aims to transmit knowledge about economic, social and environmental areas through the interactions among the cards. This game can be played by 3 to 6 players over 15 years old and lasts around 60 minutes.
   The main references used for designing iPolito cards and rules are "Bang" and "Uno" card games.
   The messages enclosed in iPolito involved the use of technologies applicable within the campus that aim to achieve 2030 objectives through interconnection of the SDGs.
   This is the reason why the students decided to address the following SDGs: SDG 4- Quality Education, SDG 7- Affordable and Clean Energy, SDG 9- Industry, Innovation and Infrastructure and SDG 11- Sustainable Cities and Communities.
   This game is composed of 5 main packs of cards, respectively "decision cards" with an immediate effect on the match, "objective cards" that contain the player's final objective and bonus, "strengthening cards" (*Figure 31*) which are involved the technologies to execute during the match, "unforeseen cards" with events, disaster, malus or interruption of the game's rhythm and finally the "multiplayer decision cards" that represent elements of relationship and exchanges. Dashboards and pieces help players to count the points during the match. The game ends when one player achieves first his end-of-game objective.

Figure 31_ Pack of cards about strengthening that player can realize during the game

[29] Developers: Baldi Alessandro, Ciccarelli Mario, Colonna Federico, Palliotto Alessandro, Ponzetti Davide, Restagno Marco, Tiblias Federico

5. **PolitoGreenMission** [30] developed by Group 5, is a cooperative multiplayer board game, playable for 3 to 8 players. This game was created drawing inspiration from Cluedo (the type of board and movement) and Pandemic (cooperation element).
In this game SDG 6- Clean Water and Sanitation, SDG 7Affordable and Clean Energy, SDG 12- Responsible Consumption and Production are addressed. In PolitoGreenMission, sustainability is a goal that to be reached together and in which collaboration is a key factor. Sustainability is not free, but has a price in terms of time spent, personal satisfaction and available investments. In PolitoGreenMission, the player can choose a specific role from 3 alternatives: students, professors and rector of Politecnico di Torino. The main objectives of PolitoGreenMission refer to solve sustainability issues that gradually arise during the play trade-offs between instantaneous and long-term optimization (*Figure 32*).
The creativity phase was characterized by research done to define mechanics, cards and effects together with analyses of the past projects carried out over the last year within the talents program.
To win this game, the players have to realize at least 3 projects that solve long-term sustainability issues within the campus.
Otherwise, the players get lost when running out all the resources of the Politecnico di Torino or when the indicators of satisfaction of players reach level 0.

Figure 32_ Example of "artefact card" that shows green ETICS system cured and kept by students

[30] Developers: Bosio Riccardo, Buffa Filippo, Ferrero Marco, Giambrone Ivan, Nargiso Luigi Pio, Nicola Alessandro, Scarzello Marco, Sega Gabriele

6. **4…3…2…1…Sustainability** [31] is a competitive and challenging board game created by group 6. It is designed for 4 players that have to invest money and limited resources in sustainable projects within the campus of Politecnico di Torino. This game draws inspiration and references from Risiko (spatiality, strategy and secondary objectives), Blood Rage (graphic) and Terraforming Mars (resources, parameters, "action cards"). This game concerns SDG7- Affordable and Clean Energy, SDG11- Sustainable Cities and Communities (for a more sustainable campus), SDG13- Climate action (improvements) and SDG17- Partnership for the goals (collaboration among the players to realize special projects), to increase especially 3 sustainable parameters: energy efficiency, reduction of CO2 emission and student wellbeing. The players have to obtain the maximum number of sustainable points, through sustainable actions (*Figure 33*), to win the game. The game is organized into 3 main parts, the first one concerns investment in sustainable projects to be realized within the campus through "project and event cards", the latter concerns the realization of improvements and the last one involves the acquisition of project revenue.
The game board represents the main buildings of the floor plan of the campus in which the players can play their action cards. The latter is related to projects and initiatives that can be realized such as photovoltaic plants, sustainability festivals, renewable energy research centres and investments in sustainable shares. In 4…3…2…1…Sustainability: the winner is the one with most sustainable points at the end of the game.

Figure 33_Example of action cards in 4...3...2...1...Sustainability

[31] Developers: Anselmo Sebastiano, Calogero Lorenzo, Capano Francesco, Fagiolo Riccardo, Gaudioso Renato, Giffoni Gioacchino, Marrocu Emma, Sanfilippo Matteo

7. **Polinks**[32] is a competitive card game developed to establish links and connections among different workable actions for the campus of Politecnico di Torino. The players impersonate one of the members of the well-known internal Green Team and deal with a specific area among water and food, waste, transport and green areas or energy. In particular, this game tackles SDGs such as SDG6- Clean Water and Sanitation, SDG7- Affordable and Clean Energy, SDG9- Industry, Innovation and Infrastructure, SDG11- Sustainable Cities and Communities, SDG12- Responsible Consumption and Production, SDG13- Climate Action and SDG17- Partnership for the goals. Nevertheless, each player only concentrates on his area of competence, gaining advantages from the weakness of the other players. This game was designed for 4 players and its duration can vary between 30-45 minutes per match. The main components of the game involve a single deck for each player according to the specific area, a common dashboard in which players arrange their cards, and coloured stickers for counting points. The main way to score points is to define connections with the other packs of cards. These connections can be defined as synergies when there is a positive relationship between two cards; they are defined trade-offs when the relationship is negative. These connections are sometimes visible and clearly defined on the top of the cards as a bonus or malus, as shown in *Figure 34*, but sometimes they are hidden to make the game more challenging. The game ends when the dashboard is covered by cards and the player with has the greatest number of points wins.

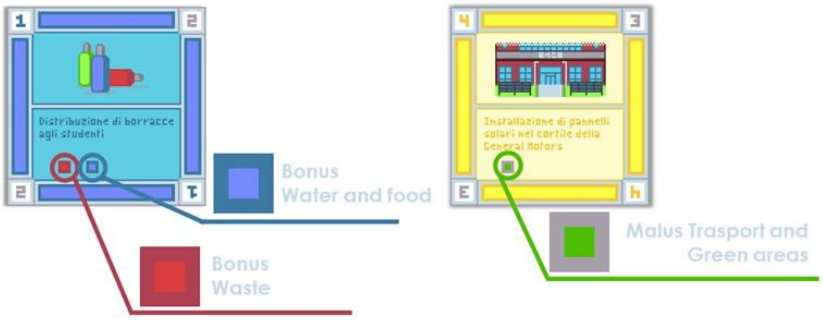

Figure 34_Example of bonus and malus links illustrated on the top of the cards in Polinks

[32] Developers: Barresi Sebastiano, Fedozzi Marco Gabriele, Leva Daniele, Notarangelo Matteo, Pisciotta Horner Steven, Ponso Alberto, Scipi Enrico, Ziparo Vincenzo

8. **Green Rush**[33] is a competitive multiplayer card game, designed for 4 players. The main aim of the game is to raise awareness and inform players about conscious consumption of resources inside the campus, by spreading culture and good practices related to sustainability for the achievement of the SDGs.
   In this connection, Green Rush involved SDG3-Good health and wellbeing, SDG4- Quality Education, SDG6-Clean Water and Sanitation, SDG7-Affordable and Clean Energy and SDG12-Responsible Consumption and Production. This game is designed for university students but can be played by everyone.
   Green Rush takes place in 5 polytechnic sites located in the city of Turin: Main campus, Lingotto, Castello del Valentino, Mirafiori and Cittadella. Each of them has precise characteristics represented in different pack of cards "Resource", "Objective" and "Problem". In conformity with the SDGs, 4 main sustainable indicators allow players to keep track of the progress of the game. They are respectively: Water (SDG6), Welfare (SDG3, SDG4), Waste (SDG12) and Energy (SDG7). Each player must complete his personal challenge, defined at the beginning of the game, in front of his opponents, in accordance with his turn. Through the use of "project cards" (*Figure 35*) players can gain or lose points for each indicator. During the game, however, players must keep an eye on the value of the critical threshold to avoid losing all the points and thus also the game.

Figure 35_ An example of "project card" to implement in Green Rush

[33] Developers: Battaglia Andrea, Ciliegi Paola, Foglia Parrucin Lorenzo, Paglieri Davide, Paliani Simone, Terrone Pietro, Vaccaro Francesco

5.4 The Challenge assessment

The assessment of objectives of the challenge was conducted using 2 questionnaires. These questionnaires were carried out thanks to the collaboration with one of the four tutors, Francesco Strada, PhD candidate at DAUIN [34] Politecnico di Torino. All the work was supervised by Professor Isabella Lami.
The first questionnaire was carried out to evaluate the quality of the serious games developed, analyzing to what extent sustainability themes were addressed. This questionnaire was submitted to 4 professors and 4 tutors involved in the challenge who, upon extensive play sessions, answered specific questions.
The second questionnaire was designed to qualitatively assess students' experience and appreciation of this alternative form of ESD intervention. At the end of the Challenge, we submitted this questionnaire to all 59 students. Using the results obtained, this assessment aims to address the research question related to understanding whether the Challenge is a compelling and effective new approach for ESD.
In the following sections, the questionnaires' details will be described and the results will be presented and discussed.

5.4.1 Q.1: Professors and Tutors Questionnaire

The first questionnaire was created for the final evaluation of all the serious games made by 59 students in order to establish the winner of the challenge. This questionnaire, namely "Evaluation questionnaire: Talenti Polito Challenge – "Promoting the sustainability of university campuses through serious games", was submitted to 4 professors and 4 tutors to evaluate the final 8 serious games. The questionnaire was filled in after completing some research towards existing surveys which evaluate knowledge transfer and learning experience in educational serious games. Among the surveys found (Connolly, Stansfield, and Hainey, 2007; Von Wangenheim, Kochanski and Savi, 2009; Von Wangenheim and Shull, 2009) the one realized by Savi et al. (2011) was found to be the most appropriate to use for reference purposes. This is MEEGA- A Method for Evaluating Educational SE Games, where SE means Software Engineering.
MEEGA is a method used for the evaluation of SE games in educational contexts, defining a model that facilitates and systematizes evaluation of a student's reaction to educational games in terms of motivation, user experience and learning effectiveness (Savi et al., 2011).

[34] Department of Control and Computer Engineering (DAUIN)

The MEEGA model focuses on evaluation level 1 (reaction_ Kirkpatrick) by capturing student's reactions after they played games, through a standardized questionnaire, by measuring 3 dimensions: Motivation, User experience and Learning. It uses the ARCS model (Attention, Relevance, Competence, Satisfaction) and was developed using Goal, Questions, Metrics- GQM (Basili et al, 1994) to explicitly define a measurement program. For this reason,
MEEGA is deemed acceptable in terms of its applicability, usefulness, validity and reliability, by offering an alternative to evaluate games in a non-intrusive way. This is why we decided to create our questionnaire based on MEEGA's characteristics. *Table 19* shows the final version of the questionnaire that we submitted to professors and tutors at the end of the Challenge.

Table 19_ Evaluation questionnaire: Talenti Polito Challenge – "Promoting the sustainability of university campuses through serious games"

Item no.	*Dimension*	*Item*	*Type*
Sub-component Motivation			
1	Attention	The game design is attractive.	5 item Likert
2	Attention	The variation (form, content, or activities) helped me to keep attention to the game	5 item Likert
3	Confidence	It was easy to understand the game and start using it as study material	5 item Likert
Sub-component User Experience			
4	Social Interaction	The game promotes moments of cooperation between the players	5 item Likert
5	Social Interaction	The game promotes moments of competition between the players	5 item Likert
6	Challenge	This game is appropriately challenging for me, the tasks are not too easy nor too difficult	5 item Likert
7	Challenge	The game progresses at an adequate pace and does not become monotonous - offers new obstacles, situations, or variations in its tasks.	5 item Likert
8	Fun	I had fun with the game	5 item Likert
9	Fun	I would recommend this game to my colleagues.	5 item Likert
10	Competence	I achieved the goals of the game by applying my knowledge.	5 item Likert
11	Fun	I would like to play this game again.	5 item Likert
Sub-component Learning			

12	Short-term learning	How much do you think the game contributed to your learning about sustainability?	5 item Likert
Sub-component Evaluation			
13	Consistency and fulfilment of requests	How well do you think the game has properly addressed the theme of the SDGs?	5 item Likert
14	Consistency and fulfilment of requests	How coherently do you think the game was set on the campus?	5 item Likert
15	Consistency and fulfilment of requests	How much do you think the game has respected, in general terms, the initial demands of the challenge (serious aspect, sustainability theme, campus setting)?	5 item Likert
16	Overall evaluation of the game	What final assessment would you give, taking into account all the aspects addressed, to the serious game just played?	5 item Likert

The original version of MEEGA provides 27 questions divided into 3 main sections known as the Motivational component, User experience component and Learning component. Our version added an evaluation component to assess consistency and how far requests were fulfilled by the students. Therefore, our version is organized in 16 questions subdivided into 4 different sections, respectively: Motivational component, User experience component, Learning component and Evaluation component.

We asked the professors and tutors to answer the questions by using a 5-point Likert scale (1-completely agree, 2-disagree, 3-indifferent, 4-agree, 5-completely agree).

The questionnaire was filled in by professors and tutors at the end of each game. They were provided with a Google form link they could access. At the beginning of the questionnaire, they were asked to indicate which game they had just finished playing. Furthermore, a maximum time limit of 10 minutes was given in which to answer all the questions. A total of 64 responses were received from 8 players and evaluators (to teachers and 4 tutors) for a total of 8 serious games. This evaluation questionnaire was analyzed purely for research purposes, research and statistical analysis; hence anonymity was guaranteed.

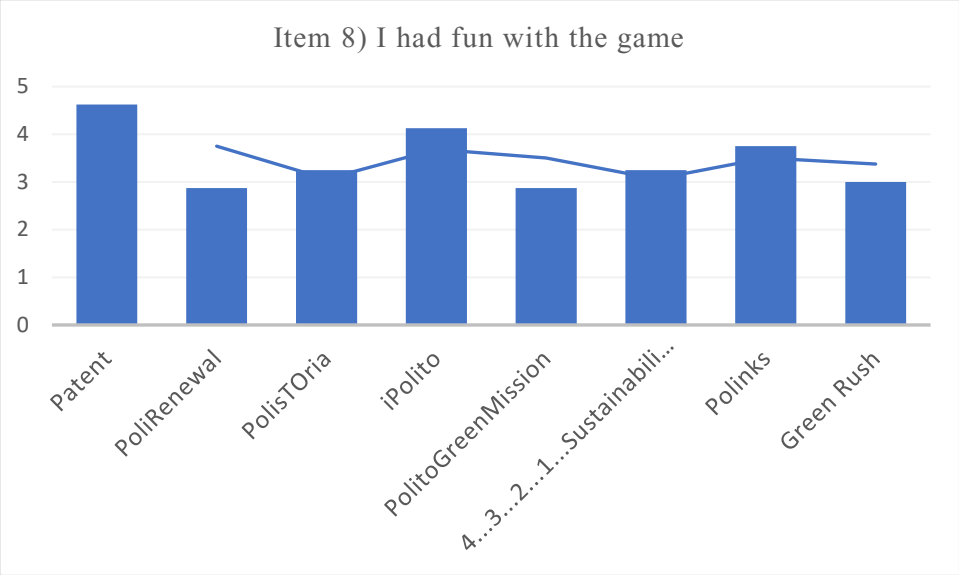

Figure 36_ Results of games' contributions in terms of fun

The outcomes obtained were positive. They show good satisfaction with the games produced by both the professors and the tutors involved. Regarding motivational component and user experience, 35.9 % of the players had fun during game sessions (*Figure 36*) and 25% of the players want to play again. Furthermore, for the learning and evaluation component, 31.1% of the serious games contributed to knowledge of sustainability (*Figure 37*) and 37.5 % correctly addressed SDGs.

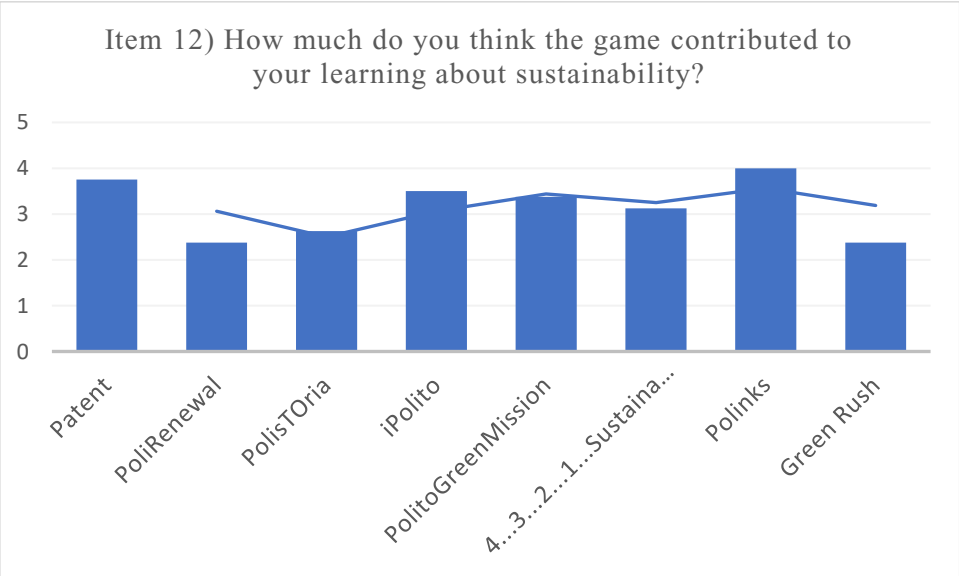

Figure 37_ Results of games' contributions for learning sustainability

Based on all the results obtained, the winning serious games are: i) Patent (1st place) a cooperative game where players are the main characters of the sustainable transition and have to obtain as many sustainable points as they can as fast as

possible by the end of the game; ii) “Polinks” (2nd place) a competitive card game developed to establish links and connections among different actions workable for the campus; iii) “iPolito” (joint 3rd place) that aims to transmit knowledge on sustainable development areas through the interactions among the cards in which the winner is the one who first reaches his game-objective and finally iv) “4…3…2…1…Sustainability” (joint 3rd place), a challenging board game where players have to invest money and limited resources in sustainable projects within the campus.

5.4.2 Q2: Challenge experience questionnaire

The post-experience questionnaire was completed by nearly all 59 students who answered the 68 items, organized into four main parts and composed of both open questions and statements to which participants had to express their agreement using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The first part was aimed at collecting information on students' habits playing digital and non-digital games, and their background knowledge and experience with making games. The second part was focused on assessing the challenge experience overall according to three sub-scales: (i) Teamwork evaluating the students' perceived effects on teamwork abilities fostered by the challenge, (ii) Learning Effect, self-assessed learning effectiveness of the challenge, and (iii) Willingness to Repeat, indicating the likelihood of students to repeat a similar experience, also in contexts different from ESD. In this part, we also asked students to self-evaluate their knowledge on sustainability themes according to the three macro-dimensions of Environment, Economic and Social. These questions were the same as the ones in the initial questionnaire students had to answer at the start of the challenge. In the third part, we examined the individual stages of the Challenge to identify commonly adopted practices and highlight the main difficulties faced by students. Finally, in the last part, we gathered students' personal information (e.g., gender, age, field of studies).

Questions were either adapted from questionnaires used in similar activities (Hava et al., 2020; Marlow 2012; Garneli et al., 2017) or newly formulated to account for our particular investigation needs. Descriptive and inferential statistical methods were used to analyze the collected data. For frequency analyses, responses 4 and 5 on the Likert scales were aggregated to indicate agreement or positive viewpoints.

After processing the data, we conducted interviews with some of the developers of the winning games: Patent, Polinks, iPolito and 4…3…2…1…Sustainability. 28 students volunteered to answer some questions to address some findings which we struggled in giving a clear explanation about some issues addressed during the challenge and clarifications on how the SDGs were treated in the games. Results

from these interviews were used to identify the game elements that were the subject of the analytical flow chart tests. The data collected from the interviews are reported in Appendix A; the analytical flow chart will be further explored in Chapter 6.

Table 20_ Questionnaire submitted to the students for assessing the challenge experience

Category		*Question*	*Type*	*Values*
Part 1_Gaming Background				
Playing Games				
	1.5	How often do you play digital games?	multiple choice	Daily/Several Times a Week/Several Times a Month/Several Times a Year
	1.6	How often do you play non-digital games? (Board games)	multiple choice	Daily/Several Times a Week/Several Times a Month/Several Times a Year
	1.7	Have you ever played a serious game, digital or non-digital?	dichotomic	yes/no
	1.8	If Yes, in which context? Was it in school?	open	
Making Games				
	1.9	Have you ever developed or contributed to the development of a game?	dichotomic	yes/no
	1.10	If Yes what type?	multiple choice	digital/non-digital/both
	1.11	If Yes could you briefly describe the context? Was it in school, a personal project, etc.	open	
Part 2_Challenge Stages Evaluation				
		Each game stages must be described before the questions so the users are aware of the meaning of each stage		
Start				
	2.1	The requirements given at the beginning of the course were adequate	5 item Likert	strongly disagree->strongly agree
	2.2	I would have preferred more requirements (e.g., specific game mechanics, a detailed theme, ...)	5 item Likert	strongly disagree->strongly agree
	2.3	I would have preferred more requirements for designing serious games	5 item Likert	strongly disagree->strongly agree
	2.4	Choose among these course activities which should have been more structured	multiple choice (multiple selections)	schedule/readings/assignments/due dates/expectations/other
Brainstorming				
	2.6	Evaluate the relevance of each activity that best identified your moment of brainstorming		
	2.6.1	general discussion	5 item Likert	not relevant -> extremely relevant
	2.6.2	research on fundamental game elements	5 item Likert	not relevant -> extremely relevant
	2.6.3	research on sustainability related themes	5 item Likert	not relevant -> extremely relevant
	2.6.4	sketches	5 item Likert	not relevant -> extremely relevant
	2.6.5	game examples	5 item Likert	not relevant -> extremely relevant
	2.7	Did you identify the target audience for your game?	open	
	2.8	If yes, did you collect information about the target audience?	dichotomic	yes/no
Design				
	2.10	Did you have any difficulties in the design stage?	dichotomic	yes/no

	2.11	If yes, please explain these difficulties.	open	
	2.12	Did you have any difficulties basing the game on sustainability topics?	dichotomic	yes/no
	2.13	What resources did you use during your research information on the game topic?	open	
Development: MVP				
	2.11	Did you have any difficulties in the development stage?	dichotomic	yes/no
	2.12	If yes, please describe these difficulties	open	
	2.13	Researching the target audience and the game topic was important during the game development process.	5 item Likert	strongly disagree->strongly agree
	2.14	Identifying the game components (mechanics and dynamics) was important during the game development process	5 item Likert	strongly disagree->strongly agree
	2.15	Paper prototyping was important in the game development process.	5 item Likert	strongly disagree->strongly agree
Playtesting				
	2.17	Quantify the number of playing sessions you completed during the playtesting phase	multiple choice	1-10/11-30/31-60/61-100/100+
	2.18	This phase was relevant in defining the final version of the game	5 item Likert	strongly disagree->strongly agree
	2.19	Have you changed some mechanics, game elements, characters during this phase?	dichotomic	yes/no
	2.20	If Yes, what did you change?	open	
	2.21	Did you test the game with external people?	open	
	2.22	Do you recall any defining moments that occurred during playtesting which contributed to relevant changes in the game?	open	
	2.23	The impact of tutors' feedback was relevant during this stage	5 item Likert	strongly disagree->strongly agree
	2.24	Evaluate the contribution, during each phase, given by the tutors	open	
		start	5 item Likert	strongly disagree->strongly agree
		brainstorming	5 item Likert	strongly disagree->strongly agree
		design	5 item Likert	strongly disagree->strongly agree
		development: MVP	5 item Likert	strongly disagree->strongly agree
		playtesting	5 item Likert	strongly disagree->strongly agree
		Evaluate the contribution, during each phase, given by the professors		
		start	5 item Likert	strongly disagree->strongly agree
		brainstorming	5 item Likert	strongly disagree->strongly agree
		design	5 item Likert	strongly disagree->strongly agree
		development: MVP	5 item Likert	strongly disagree->strongly agree
		playtesting	5 item Likert	strongly disagree->strongly agree
Part 3_Overall Challenge Evaluation				
Teamwork				
	3.1	Collaborating in a team at the development of the game has been challenging	5 item Likert	strongly disagree->strongly agree
	3.2	The current Covid-19 situation has negatively affected the group work	5 item Likert	strongly disagree->strongly agree
	3.3	My contribution to the team’s final output was fair and adequate.	5 item Likert	strongly disagree->strongly agree
	3.4	The team was organized and structured suitably for the tasks it had to perform	5 item Likert	strongly disagree->strongly agree

Sustainability Dimensions Knowledge				
	3.5	Environment	5 item Likert	no knowledge -> excellent knowledge
	3.6	Economic	5 item Likert	no knowledge -> excellent knowledge
	3.7	Social	5 item Likert	no knowledge -> excellent knowledge
Challenge Learning Effect				
	3.8	Evaluate the relevance of each stage to learning sustainability-related themes		
	3.8.1	Start - Challenge Requirements and First Lectures	5 item Likert	not relevant -> extremely relevant
	3.8.2	Brainstorming - Evaluating Ideas for the Serious Game	5 item Likert	not relevant -> extremely relevant
	3.8.3	Design of the Game	5 item Likert	not relevant -> extremely relevant
	3.8.4	Development: MVP	5 item Likert	not relevant -> extremely relevant
	3.8.5	Playtesting	5 item Likert	not relevant -> extremely relevant
	3.9	The challenge has contributed to the deepening of sustainability-related themes	5 item Likert	strongly disagree->strongly agree
	3.10	The challenge offered an immersive learning experience	5 item Likert	strongly disagree->strongly agree
	3.11	I will adopt what I learned during the challenge in my daily life	5 item Likert	strongly disagree->strongly agree
	3.12	Compared to other activities completed in Percorso Talenti, how do you feel about this type of learning by making a serious game? Describe it with three words	open	
	3.13	What was the best thing you learned from the challenge?	open	
Future Activities				
	3.14	I would like to repeat the activity of creating a serious game as a means to deepen or learn another subject instead	5 item Likert	strongly disagree->strongly agree
	3.17	After the challenge experience, I am more inclined to play serious games	5 item Likert	strongly disagree->strongly agree
	3.18	This type of activity should become part of the normal teaching procedure	5 item Likert	strongly disagree->strongly agree
	3.20	What would you change in the organization of a future challenge with the same goal of creating a serious game?	open	
Part 4_Personal Info				
Personal Info				
	4.1	Gender	multiple choice	M/F/Other
	4.2	Age	open	
	4.3	What is your field of study?	open	
	4.4	Which was your group number	multiple choice	group numbers

5.4.3 Findings and discussion of Q2

Of the 58 respondents to the post-experience questionnaire, 93% were male, aged 21-22 and were evenly divided between those who frequently play digital games (47%) and those who less frequently do (53%). Only 12% reported playing non-digital games regularly, and 37% had experience playing serious games either digital or not, primarily in an academic or learning context (e.g., high school or University). Concerning their background with creating games, students were mainly at their first experience (75%), and for those who had previously developed a game, it was usually for personal reasons (Cravero et al., 2021).
53 students (*Figure 38*), making up 61 % of respondents, positively evaluated the learning effects solicited by the challenge (i.e., Learnability sub-scale) alongside 65% of all respondents who reported improved teamwork ability fostered by this experience (i.e., Teamwork subscale).

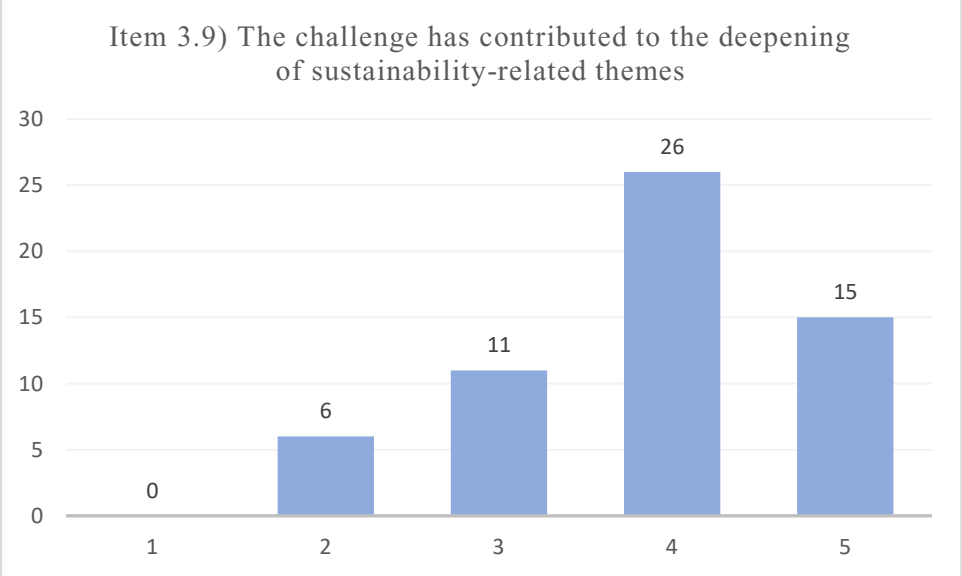

Figure 38_Learning effects solicited by the challenge

Unfortunately, only 37% (24 students as shown in *Figure 39*) expressed their likelihood of repeating a similar experience in the future (i.e., Likeability to Repeat sub-scale) (Cravero et al., 2021). However, we detected a high correlation (0.76) between the Learnability and Likeability to Repeat sub-scale, suggesting that the learning experience provided by the challenge, gave no reason not to repeat a similar activity in the future.

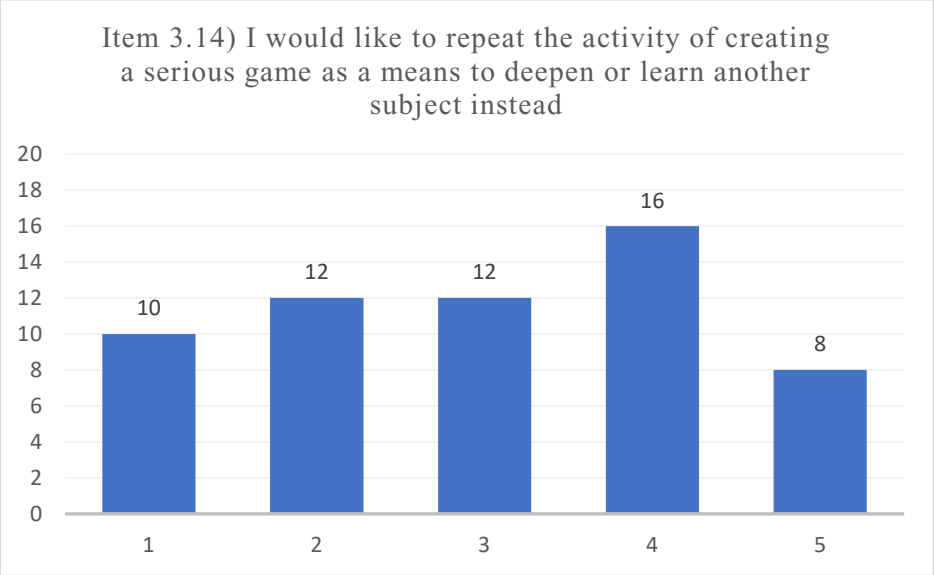

Figure 39_ Likeability to repeat a similar experience

This is an important finding because it highlights the positive impact a similar activity (i.e., learning by making a serious game) can have on learning and shifts the focus on what did not work onto something else. What emerged from the interviews is that the main reason students negatively assessed the Likeability to Repeat subscale was due to their difficulty at the beginning of the Challenge, mainly during the design phase (64% of students).

Moreover, these difficulties were primarily caused by the current pandemic situation, which forced students to work remotely without ever having the chance to meet in person. It must be underlined that all students came from different learning backgrounds and had never met before the challenge. According to the students' feedback, this limitation compromised their ability to establish a positive bond, rapidly resulting in an initial lack of group work commitment. This jeopardized the brainstorming and initial design stages which, according to them, required countless hours to establish a commonly agreed idea. Based on past experiences, the majority of students agreed that the main issues could be overcome if a similar activity had been carried out in person. Also, it must be stressed that the majority of students had for no background knowledge of game design or development. However, the challenge initial guidance steps were, according to the pre-covid plan, mainly focused on providing basic knowledge on these topics. Nevertheless, we were forced to reschedule most of the lectures and ended up delivering them too late in the design stage. However, once the game was designed and the development started, most difficulties were overcome. As a result, we detected a significantly lower percentage (39%) of students who declared having faced difficulties during this stage. Furthermore, positive learning effects were also detected from the questionnaire items in which students were asked to self-evaluate

their knowledge across the three sustainability dimensions (i.e., Environment, Economic and Social). To compare statistical significance differences with the same questions, submitted at the beginning of the challenge, we performed a MannWhitney U test. We obtained significance (alpha < 0.05) across all dimensions as follows: Environment (alpha = 0.04), Economic (alpha = 1.1e-08) and Social (alpha=0.000105). Also, we detected an improvement for each dimension with different effect sizes (Cohen d) as follows: Environment small (0.358), Economic large (1.189) and medium (0.761) (Cravero et al., 2021). These values were computed from the MannMann-Whitney U test, according to the approach described in Fritz, Morris, and Richler (2012). These results show a positive and detectable influence solicited by the challenge. Based on the interviews we conducted, the majority of students agreed that the greater impact (i.e., large effect size) detected for the Economic dimension might be attributed to the lower level of familiarity students have with this dimension compared to the Environment and Social ones. Thus, the challenge was a chance for them to gain further knowledge on this. When designing the challenge, the scientific responsible, the team of professors and tutors structured it by imagining a learning experience that would yield no outcome difference regarding the student's background experience with either playing or making games. Assuming this hypothesis, we evaluated statistical differences for all the overall sub-scale items (i.e., Learnability, Teamwork and Likeability to Repeat) and the Sustainability Dimensions Knowledge across difference groups derived from the gaming background information we gathered in the questionnaire. To test statistical differences, we used either a standardized T-Test or a Mann-MannWhitney U test based respectively on the normality or non-normality of the sample, measured through a Shapiro Wilk test. All these subscales showed no statistical difference (alpha > 0.05) between users who had a different experience and familiarity with either playing digital-games or playing serious games. We were unable to carry out the same comparison for the groups of non-digital players and those who had previous experience with making games because the sample sizes of those categories were too unbalanced. However, this is a promising finding because it shows that to benefit from the positive effects an experience like this can deliver, the level of familiarity with the gaming medium is not a direct cause.

5.4.4 Q.3: Students' interviews on challenge-winning games

At the end of the Challenge, we conducted structured interviews on a smaller group of 32 students to get more precise explanations on how they designed the cards concerning sustainable projects, actions, practices or behaviours. We interviewed students belonging to group 1 (Patent), group 7 (Polinks), group 4 (iPolito) and group 6 (4...3...2...1…Sustainability).
These interviews aimed also to clarify how students created interlinkages between sustainability goals and game mechanics. The questions that were asked to the interviewed students concerned respectively:

- the number and type of SDGs addressed in the game
- the quantity and frequency of references to the SDGs
- the way in which a particular goal was developed through game elements
- the identification of a game element also on the basis of the 3 macro dimensions of sustainability
- the synergies with other goals
- the trade-offs with other goals

Table 21_ List of SDGs addressed in challenge-winning games

Serious Games	Paten	iPolito	4…3…2…1…Sustainability	Polinks
SDG 4		X	X	
SDG 6	X		\	X
SDG 7	X	X	X	X
SDG 9	\	X		X
SDG 11	X	X	X	X
SDG 12	X			X
SDG 13	X		X	X
SDG 17			X	X

As shown in *Table 21*, interviews with students in the winning groups revealed that the SDGs most frequently addressed in the Challenge were: SDG 4- Quality Education, SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 9- Industry, Innovation and Infrastructure, SDG 11- Sustainable

Cities and Communities, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action and SDG 17- Partnerships to achieve the Goal. Respectively:

- SDG7, SDG11 and SDG13 are the goals addressed in all 4 serious games
- SDG6 and SDG12 are the goals faced in 3 out of 4 serious games

SDG4, SDG9 and SDG17 are the goals least addressed in a maximum of 2 serious games out of 4. .

Table 22 is the table used during the online interviews with students. It is structured according to 3 macro areas of sustainability, the list of main SDGs covered and how the goals were addressed.

Table 22_ Model for the assessment of sustainable interlinkages in serious games

SDGs and Targets	**Short description**	**Yes/No**	**Name of the serious game**		
Dimensions			**Social-Human wellbeing**	**Environment**	**Economic**
SDG-4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all				
How?					
SDG-6	Ensure availability and sustainable management of water and sanitation for all				
How?					
SDG-7	Ensure access to affordable, reliable, sustainable and modern energy for all				
How?					
SDG-9	Build resilient infrastructure, promote inclusive and				

	sustainable industrialization and foster innovation				
How?					
SDG-11	Make cities and human settlements inclusive, safe, resilient and sustainable				
How?					
SDG-12	Ensure sustainable consumption and production patterns				
How?					
SDG-13	Take urgent action to combat climate change and its impacts				
How?					
SDG-17	Strengthen the means of implementation and revitalize the global partnership for sustainable development				
How?					

5.5 Discussion and limitation

Talenti Polito Challenge has been proposed as a novel approach to ESD, allowing university students to challenge themselves by developing serious games with the aim to encourage sustainability awareness. This approach stems from the emerging paradigm of *learning by making* serious games instead of merely playing games. Organized in groups for three months, 59 students designed and developed appropriate serious games to raise awareness on sustainability-related themes within their university campus. Through an assessment questionnaire, the games produced were evaluated according to four subcomponent areas: motivation, experience, learning and evaluation. These areas were identified according to the

MEEGA questionnaire (Savi et al., 2011), with the purpose of valuing educational serious games. Since the model is proposed by its creators as a survey to be standardised to evaluate serious games, MEEGA was established as a reference for the first questionnaire of the challenge.

Through a post-experience questionnaire and structured interviews, we qualitatively assessed the students' experience. Results show that students positively assessed the learning effect and their improved teamwork abilities solicited by the activity. Moreover, students' self-evaluation across the three sustainability macro dimensions (i.e., economic, social, and environmental) increased from the start to the end of the challenge. Interestingly, all the positive effects measured in the questionnaire yielded no difference between students who had previous knowledge of playing or making games.

Furthermore, among the results obtained, the one concerning Item 3.11 on the choice to change one's habits in everyday life bodes well. In fact, the majority of students (58%) stated that they would like to adopt virtuous behaviours in their daily life (*Figure 40*). This result is very encouraging because they declared that they will put into practice what they learned during the challenge. The experience of learning by making, through the creation of an educational tool, led to the desired result. What was acquired through the challenge, such as recycling of polluting materials, car sharing, consumption of 0 km products or participation in sustainable campaigns, are some of the practices that can be easily integrated into daily life.

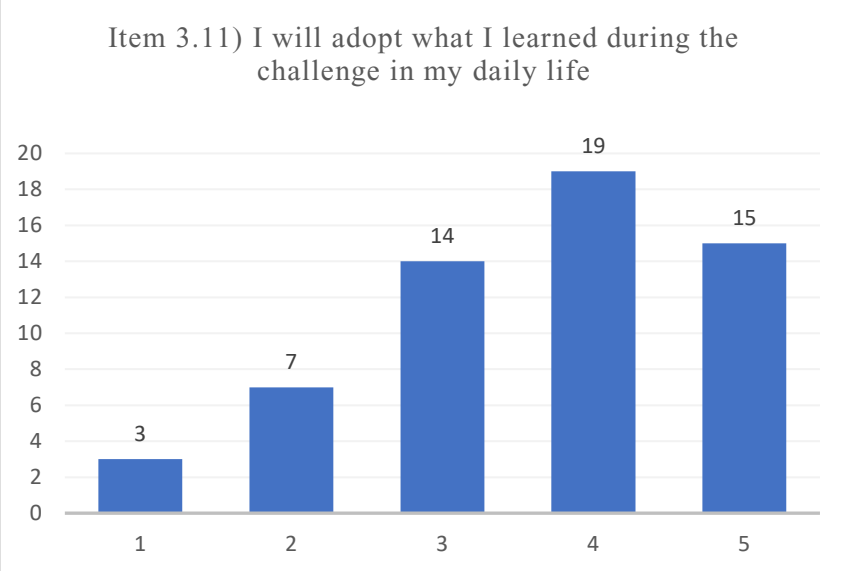

Figure 40_ Willingness to implement sustainable practices in everyday life

As a final point, the students expressed their likeability to repeat a similar experience, regardless of the Covid-19 lockdown, which had limited the execution of the project. Unfortunately, lockdown was implemented throughout the entire

experience of the challenge, forcing students to work and collaborate only in a remote way. In any case, the challenge has offered the chance to explore *learning by making* games, an effective method which may be successfully applied to an educational context. The objectives and the outcomes accomplished at the completion of this experience should help to understand what has been successful and what is to be improved in future challenges.

Nonetheless, based on the results of the second application of the analytical flow chart, it was possible to better investigated the game elements realized by the students.

Chapter 6

Application of the analytical flow chart to serious games

Since both the outcomes of the classification and the challenge showed that sustainable development and SDGs are addressed in games, it is fascinating to explore how this occurs and through which mechanical system knowledge is channeled. Therefore, following the macro steps of the exploratory sequential mixed methods, using the findings of the classification as a starting point, it was proposed to introduce an analytical flow chart to be tested on sustainable serious games.

The purpose of this analytical flow chart (Chapter 1) is to identify game elements that represent more or less explicit references to the SDGs that convey knowledge through specific game mechanics. The characteristics of this flow chart have been reported in Chapter 1 in the sub-section 1.3.2, but will be revisited here to facilitate understanding. The proposed flowchart consists of two elements necessary to explore references to the SDGs through game mechanics to understand how knowledge messages reach the players. The first one is based on the Interlinkages tool, developed by JRC researchers according to the literature review, whilst the second element refers to Werbach and Hunter's (2012) studies on game mechanics. Thus, the KnowSDG platform of JRC provides a tool to visualize the cumulated

interlinkages from a set of publications. By accessing Interlinkages, it is possible to quickly see and understand for which interlinkages there is strong agreement in the literature. In this way, connections among SDGs are investigated through a large number of synergies and trade-offs also between SDGs and targets.
Within this thesis, the analytical flow chart is tested twice and the results are provided in this chapter. The first test concerns 3 of the 67 serious games identified in the new classification (Chapter 4). These games are respectively: *Energy City*, *Urban Climate Architect*, and *New Shores*: a game for democracy.
The second test is conducted on new serious games specifically designed and developed to convey notions about sustainability issues in universities campuses. These games are those produced for the Talenti Polito Challenge and are respectively the best rated games: Patent, Polink and iPolito.
This chapter concludes by discussing the application of this proposing flow chart on serious games, with some already existing in the sustainability marketplace, others specifically designed to convey concepts of sustainability.

6.1 First test on classified serious games according to SDGs

With regards to the subjects of the analysis, the respective games were chosen: *Energy City, Urban Climate Architect*, and *New Shores*: *a game for democracy*. These games have been chosen according to some characteristics that they have in common and for other relevant reasons explained in the following lines.
All three games share an association with SDG 11- Sustainable Cities and Communities and SDG 12- Responsible Consumption and Production, which were the ones most commonly addressed in the 67 games ranked. Moreover, all three of the chosen games are available online, completely free of charge and therefore easily playable with an Internet connection from a computer. *Energy City* (https://assets.jason.org/resource_assets/8239/3733/popup.html) and *Urban Climate* Architect (https://www.clisap.de/stadtklimaarchitekt/) are directly available on their respective links. Otherwise, it is possible to play *New Shore: a game for democracy through* a request via Centre for Systems Solutions (https://newshores.crs.org.pl/#contact-us).
One of the reasons that led me to select these three games was to identify games that had been created both before and after the establishment of the SDGs in 2015. *Energy City* was launched in 2010 before SDGs were even published, while the other two were created after 2015, in 2016 (*Urban Climate Architect*) and 2017 (*New Shores*: a game for democracy) respectively.
As far as the target audience is concerned, *Energy City* is intended for students while the other two serious games are aimed at a general audience and can therefore be

played by anyone. *Energy City* can of course be played by everyone, but it is important to bear in mind that it was designed especially for educational purposes. Lastly, I have taken into consideration the category of genre for the selection. *Energy City* for instance, belongs to the category of education since, as mentioned before, it is mainly addressed to a student audience. The two remaining are simulation games and require the player to simulate urban transformation scenarios through the realisation of projects.
This chapter will explore these games in detail, individually describing and analysing them.

Table 23_ Comparative analysis among the serious games selected for the first test

Serious games	*Genre*	*Type and availability*	*Target Audience*	*Before/after SDGs establishment*	*SDGs*
Energy City	Education	Online and Free	Students	Before (2010)	SDG11 SDG12
Urban Climate Architect	Simulation	Online and Free	General Audience	After (2016)	SDG11 SDG12
New Shores	Simulation	Online and Free	General Audience	After (2017)	SDG11 SDG12

6.1.1 Application for Energy City

Energy City is a serious game that allows players to create an urban energy context that addresses economic, social and environmental issues. In Energy City, the player takes on the role of a policy maker in a world with a short supply of non-renewable resources (*Figure 41*). Moreover, Energy City was developed in 2010 by the collaboration among National Geographic, Ewing Marion Kauffman Foundation, Filament Games and the Jason Project (games4sustainability.org).
Energy City is also defined as an online single-player flash game (lasting 15-30 minutes). All that is required for playing are a computer, an internet connection and Flash Player. The main benefits of this serious game are the education on energy sources and energy policy, a simplistic training through a decision-making process, understanding the demands of the society and the simplistic training in policymaking (games4sustainability.org).
In regards of gameplay, the player must perform the following actions: i) choose one of the scenarios; ii) fill the city energy bar while meeting the demand of different interests of groups such as students, scholars, health committee; iii) harness various energy sources and iv) keep biodegradation and air pollution levels low.

Figure 41_ Example of gaming session in Energy City

Energy City comprises of the following elements:

- 6 scenarios of different city models based on climate conditions, land resources, available energy plants and types of dwelling;
- Existing energy installations;
- 4 main energy strategies;
- 2 game modes (simple level developed throughout 5 years, and hard level lasting 10 years);
- 5 different profiles of stakeholders (health council, students, residents, scientific community and business community);
- 3 main sustainability indicators: air quality, environmental impact and economic budget;
- Final graphics of the game outcomes.

As reported in the new classification, it is possible to identify some connections with game elements and SDGs. For instance, the majority of game elements covered SDG 4- Affordable education, SDG 7- Affordable and Clean Energy, SDG 11Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, and SDG 13- Climate Action. Those connections are visible in the elements highlighted illustrated in the diagram below (*Figure 42*):

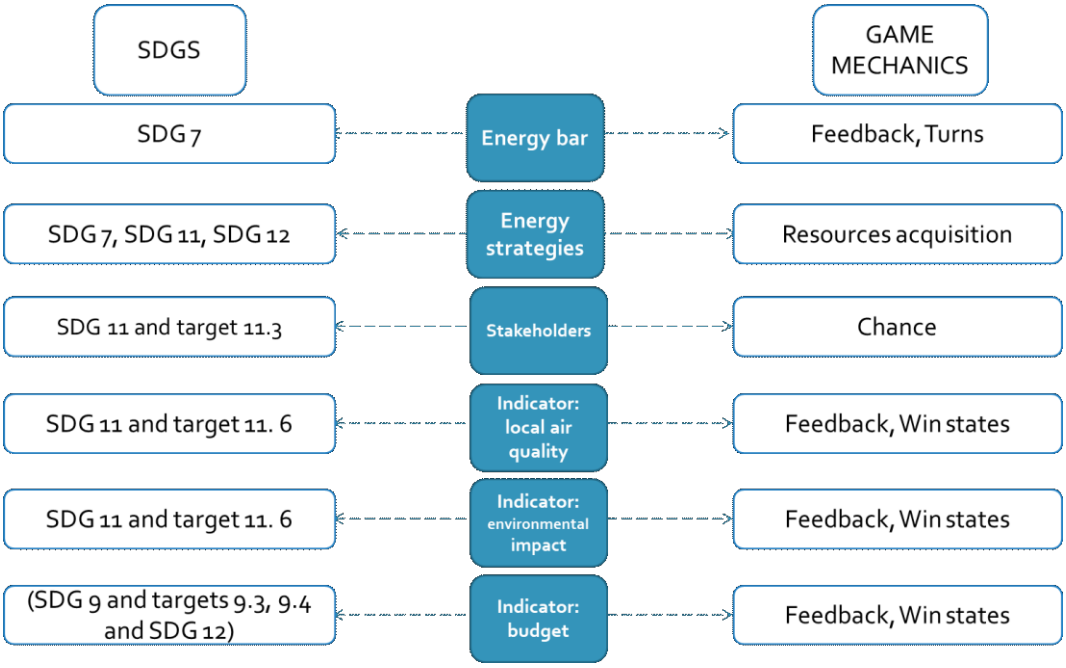

Figure 42_ Application of analytical flow chart in Energy City for identifying connections between targets' goals and game mechanics

As emerged from the application of the analytical flow chart, the game elements that play a crucial role in achieving goals are: the stakeholders, the energy strategies, the energy bar, and the three indicators of local air quality, environmental impact and budget.

From the point of view of game mechanics, stakeholders are elements of randomness namely chance, because they can make demands on the player at any time during the game. Energy strategies are instead expressed as resource gaining while the energy bar provides immediate feedback and different rounds of the game. Finally, the game indicators are recognisable both as feedback, since they immediately communicate information regarding the player's performance, and also regarding the final outcome of the game, whether it has been won or lost.

Afterwards, each game element refers more or less explicitly to the sustainable goals. For instance, according to SDG 7 the implementation of in-game energy strategies contributes to the daily energy requirement, which can be measured through the energy bar. Those strategies will be taking into account for further analysis due to their multidisciplinary effects in the game.

Otherwise, all the other elements mentioned above refer more to SDG 11. The stakeholders' element is recognizable in target 11.3 as it encourages inclusive and sustainable urbanization and the delivery of participatory, integrated and sustainable human settlement planning and management in all countries. This is due to the fact that, in Energy City, the stakeholders actively participate in the design of the city by expressing their demands several times at each turn, especially in terms of sustainable designs.

All three indicators refer to what is described in SDGs 11 and 12. Local air quality and environmental impact especially relate to target 11.6., mainly because they monitor the environmental impact of cities, also by paying particular attention to levels of air quality in Energy City.
The budget indicator, unlike the others, is not easily recognizable in a specific goal. Depending on how it is used in this game, it may be partly associated with some of the targets in SDG 9 and 12. Budget information can be associated with targets 9.2 for promoting inclusive and sustainable industrialization that "significantly raise industry's share of employment and gross domestic product".
According to target 9.4, the budget indicator helps the player in choosing investments. Through percentage values it provides the player with the amount of money that can be invested in more sustainable industrial projects and processes. In the long term, a larger financial investment can have a more profitable return. As mentioned above, the set of energy strategies includes several projects that deserve to be analysed in more detail.
Energy strategies are mainly classified according to 4 main features: nonrenewable, inexhaustible, conservation and renewable.
Among the non-renewable strategies there are oil power plants and natural gas resources. Inexhaustible energies involve projects of wind farm, hydroelectric plants (tidal power plants), geothermal plants and solar resources (PV panels). Furthermore, conservation resources include residential, commercial and transportation planning. Residential planning may include geothermal plants, PV panels and green rooftops. In contrast to this, PV panels and green business incentives are always encompassed in commercial planning instead. The same applies to bike paths and fuel cell buses, which are also under commercial planning. Finally, renewable resources comprise fuel cell technology (fuel cell cars and fuel cell buses) and biofuel power plants.
As can be seen from the strategies just described, some of these can feed back into several projects and thus be recognised in turn in several sustainable objectives. As an example, PV panels will be described using the analytical flow chart to identify possible synergies with other elements and goals.
As shown in *Figure 43*, PV panels are a system recognizable in target 7.2 and hold many synergies with some sustainable goals.
According to Interlinkages visualization tool the synergies identified are with the following SDG: SDG 1- No Poverty, SDG 2- Zero Hunger, SDG 3- Good Health and Well-being, SDG 6- Clean Water and Sanitation, SDG 8- Decent Work and Economic Growth, SDG 9- Industry, Innovation and Infrastructure, SDG 10- Reduced Inequality, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action, SDG 16- Peace and Justice Strong Institutions and SDG 17- Partnerships to achieve the Goal.
According to game design and characteristics of PV panels in Energy City,

synergies between these elements are only with some of the positive interlinkages recognized by the JRC's tool. Some of the positive effects of the implementation of PV panels can be recognised in SDG7 and SDG 8.

More specifically they have synergies with target 8.4. aiming to progressively improve, through 2030, global resource efficiency in consumption and production, endeavouring to decouple economic growth from environmental degradation. Other positive interlinkages are with SDG 9 to help build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. The implementation of PV panels contributes to the reduction of CO_2 emissions compared to the construction and use of other energy strategies, in line with target 9.4. The enhancement of scientific research, the improvement of technological capabilities of industrial sectors as declared in target 9.5 include increasingly innovative projects using solar resources, such as photovoltaic panel systems.

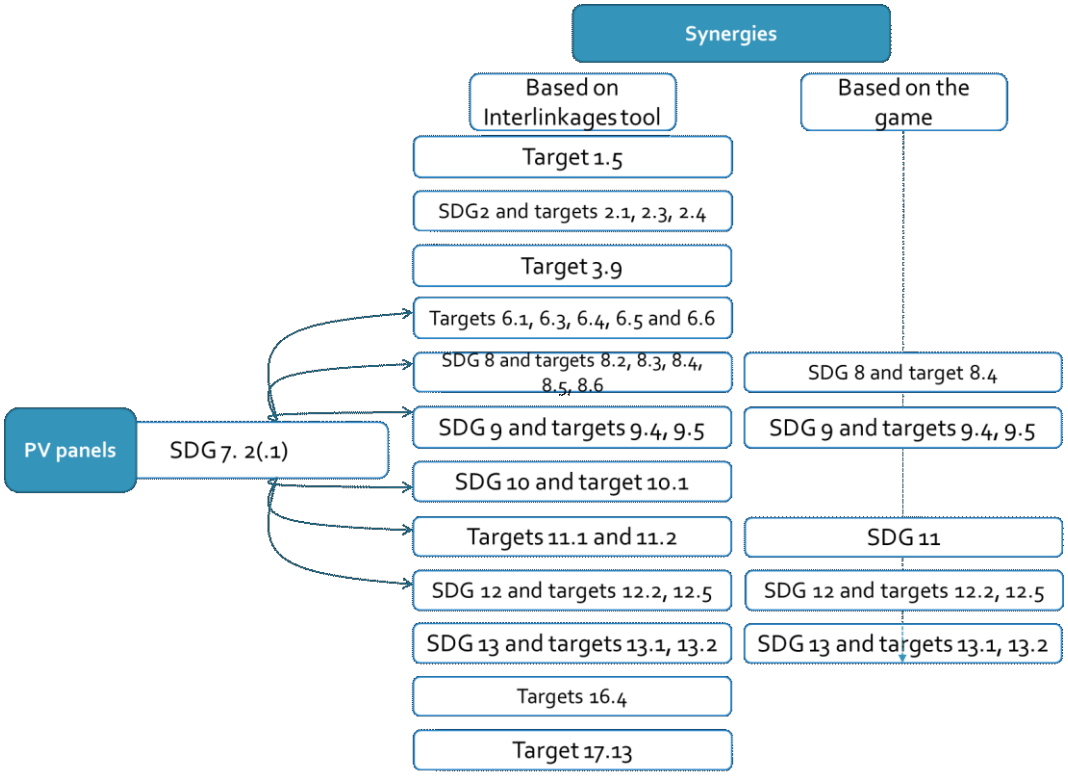

Figure 43_ Synergies of PV panels in Energy City

PV panels were conceived for this game as projects to be developed for commercial and residential planning. These systems contribute in part to the development of sustainable cities according to SDG 11. Based on SDG 12, PV panels may be among those technologies which ensure sustainable consumption and production patterns. Their use contributes also in the efficient use of natural resources (target 11.2) and to reduce waste generation through prevention, reduction, recycling and reuse (target 12.5).

Finally, according to SDG 13, PV panels can be among the actions to be taken into the fight against climate change and its impacts.

6.1.2 Application for Urban Climate Architect

Figure 44_ Example of a round in Urban Climate Architect

Throughout the world, people are constantly moving from rural to urban areas. As a result, metropolises require more housing and better infrastructures, more jobs and green spaces. At the same time, the climate is changing, and modern cities have to adapt to these new conditions. Cooling, water management, CO_2 emission and pollution are key aspects. These issues can vary greatly from region to region. Accordingly, urban planners have to take into consideration how buildings, industry, green areas and traffic affect urban climates. Solving this major challenge is exactly what players will try to do when playing *Urban Climate Architect*[35].
Urban Climate Architect is a serious flash educational game that allows players to design their sustainable cities, choosing between Europe, Asia, or America (*Figure 44*). The goal of this serious game is to realize the most sustainable personal, following the environmental demands of the game such as the provision of a sufficient number of houses according to the number of the citizens or the appropriate realization of the transport system. In this way the citizens can live well and move around the city avoiding many complications. *Urban Climate Architect* has been developed by the Urban Climate Research Team around Prof. Heinke

[35] https://www.clisap.de/discover/visuals/urban-climate-architect/

Schlünzen and David Grawe as well as the CliSAP Outreach department. The project received financial support from Hamburg's Ministry for the Environment and Energy. This is a single-player online game and it tackles several goals including SDG 6- Clean Water and Sanitation, SDG 8- Decent Work and Economic Growth, SDG 11-Sustainable cities and communities, SDG 12- Responsible consumption and production, and SDG 13- Climate action.

For what concerns game components, *Urban Climate Architect* is mainly comprised of the following game elements: 2 typologies of houses, 2 working modes, 2 types of transports, and 3 types of green areas. All these elements can be arranged according to the player's preference on the game board of 64 squares.

The progress of the game is monitored by appropriate indicators: "Housing" and "Employment" express a percentage of the number of houses and workplaces created on the game grid; furthermore, the sustainability indicators of "CO2 Emission", "Rainwater" and "Temperature" show the player in real time, and the environmental impact of taken actions.

These three indicators differ according to the city the player decides to design at the start of the game. The differences between the indicators are reminiscent of the climatic and housing characteristics of Asian, Southern American and European cities. *Urban Climate Architect* ends when the player has filled all the squares in the grid with the game elements he had at his disposal.

These game elements are precisely the subject of study of the analytical flow chart. As emerged in Figure 37, the main game elements of *Urban Climate Architect* are water systems, workplaces, houses, green areas and trees, public transports, housing and employment indicators and finally CO_2 emissions, rainwater and temperature indicators.

From the point of view of game mechanics, most elements provide instant resource acquisition and feedback as soon as they are played on the site. The only elements that differ from the others are those of the indicators. These, whether they refer to the percentage of built houses or jobs created, help the player monitor the progress of the game. At the end of the game, indicators get back to the player, through win/lose statements, updating the percentage of the population that has a home and a job.

Subsequently, each game element has more or less explicit connections with the sustainability objectives. For instance, according to SDG 6 and targets 6.6 and 6.b the player can place water systems on the game board. Jobs, which are represented in only two ways of workplace, represent SDG 8 and targets 8.3 and 8.5 according to the percentage of people employment expressed by indicators and instant feedback.

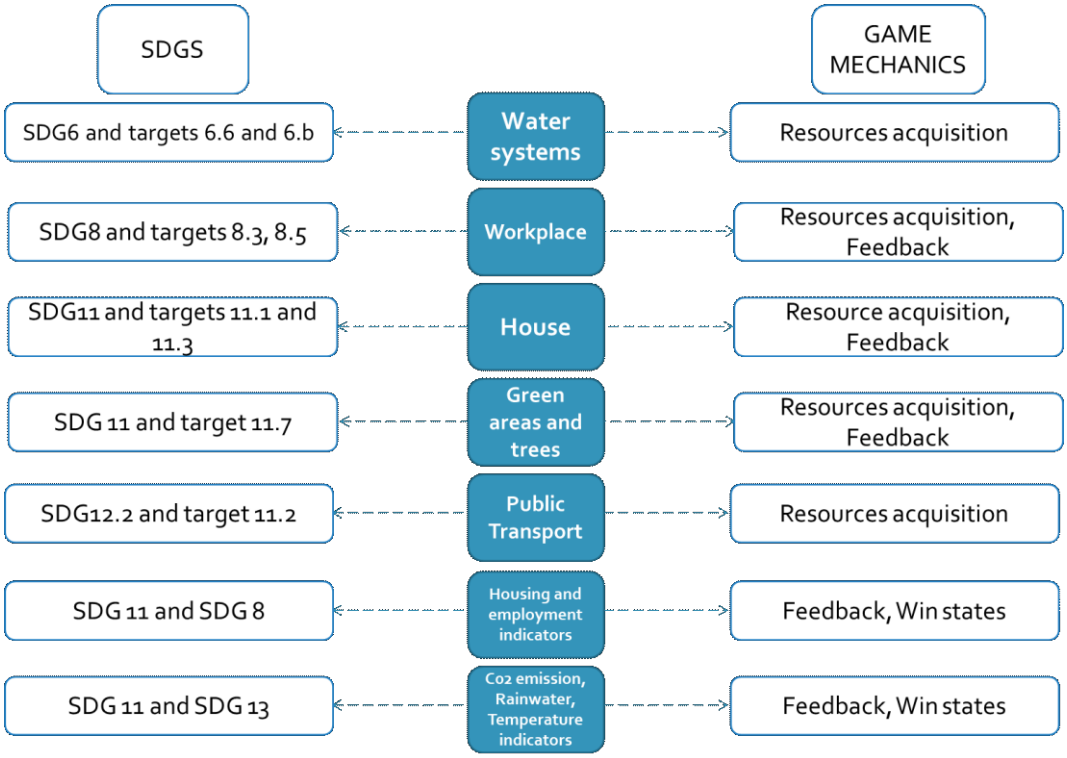

Figure 45_ Application of analytical flow chart in Urban Climate Architect for identifying connections between targets' goals and game mechanics

All remaining game elements refer to SDG 11. More specifically, *housing* refers in part to target 11.1 and more substantially to target 11.3. This is because, in *Urban Climate Architect*, the *housing* element has some congruence with sustainable urbanization and the ratio of land consumption to population growth. Furthermore, green areas and planting trees fall within target 11.7 for inclusivity and accessibility, green and public spaces. The element of public transport is recognizable in target 11.2 dedicated to accessibility and sustainable transport systems for all.

Finally, the indicators also refer to SDG 11. In particular, *employment* is also part of SDG 8 providing data on the number of jobs created. Otherwise, *sustainability* indicators refer with SDG13 according to combat climate change and its impacts by monitoring CO2 emission, rainwater and temperature values. A deeper analyses of game elements involved in SDG 11 is provided by the examples of "house" and "green areas. The analytical flow chart will be applied to identify synergies and trade-offs between selected elements.

*House*ing, as previously stated and illustrated in *Figure 46*, is recognizable in targets 11.1 and 11.3. According to the Interlinkages visualization tool, target 11.1 has synergies with SDG 1- No Poverty, SDG 3- Good Health and Well-being, SDG 5- Gender Equality, SDG 7- Affordable and Clean Energy, SDG 8- Decent Work and Economic Growth, SDG 9- Industry, Innovation and Infrastructure, SDG 10- Reduced Inequality, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action and SDG 14- Life Below Water.

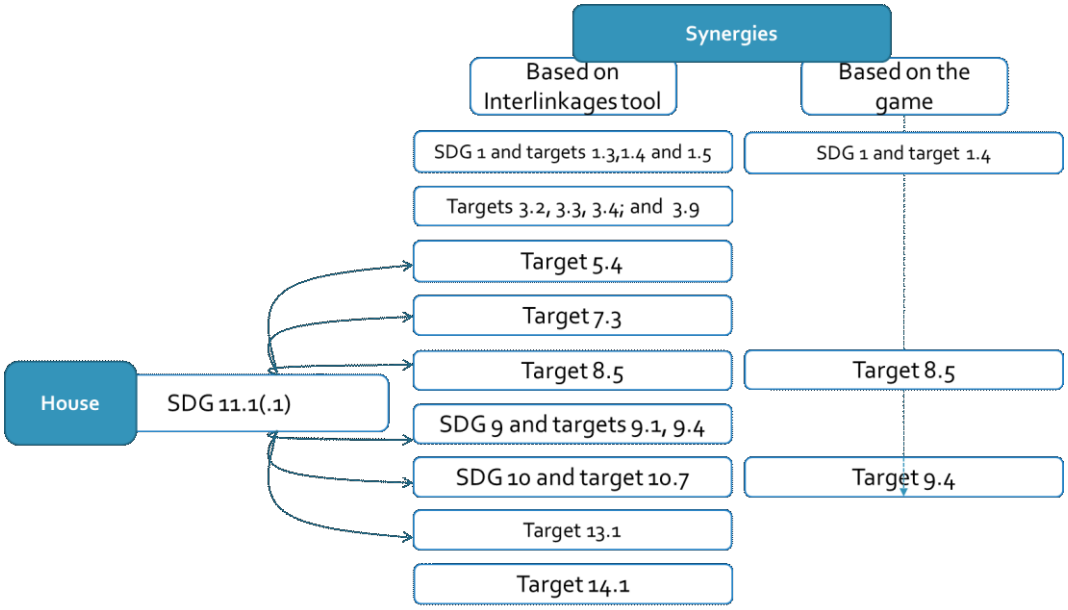

Figure 46_ Synergies of house element in Urban Climate Architect

According to game design and the characteristics of *Urban Climate Architect*, *housing* has synergies only with three of the positive interlinkages recognized by the JRC tool. These are with SDG 1 and target 1.4 according to the proportion of the population living in households, with target 8.5 because the number of houses is directly linked to the employment rate and finally with target 9.4 for CO2 emissions. Synergies of target 11.3, based on Interlinkage's tool, refer to targets 14.1, SDG 16 and target 16.6. Taking into account how the house element has been developed in the game, it has no connection with the targets defined by the tool. Otherwise, the element of green areas is recognizable in target 11.7 and based on the Interlinkages visualization tool, it has synergies only with SDG 10- Reduced Inequality. This emerged because green areas have to be accessible to everyone, but this information cannot be provided depending on how the game is structured.

6.1.3 Application for New Shores: a game for democracy

Figure 47_ Picture of the playing field of New Shores

New Shores: a game for democracy is a multiplayer online game where players are the inhabitants of a green island. The entire area of this island is covered by wild forests but an abundant amount of coal is concealed underground. The players have to defend/preserve/sustain their houses and belongings, earn money and develop public infrastructures against natural disasters. In this game players learn and explore practices that promote sustainability. Moreover, they explore correlations between greenhouse gases and climate change. Through a series of collaborations, the players practice and gain skills to communicate and apply strategies.

New Shores has been created by *Centre for System Solution* and developed within the project *Nauru Game for Active Citizenship of Youth* funded by the European Union as part of the *Erasmus+ Programme*. The game is available in four languages: English, Polish, Slovak and Hungarian (newshores.socialsimulations.org/).

Although *New Shores* is an online game (*Figure 47*), it offers social experiences as it fosters negotiation and cooperation, often triggering empathy and charitable attitudes in players. To play, all that is needed per player or team is a computer or tablet with the most recent version of Google Chrome browser installed.
Game matches can last up to two hours and are comprised of 10 rounds. In every match, more than ten players may participate.
As reported in the new classification, the main SDGs addressed are: SDG8-Decent Work and Economic Growth, SDG10-Reduced Inequalities, SDG11-Sustainable Cities and Communities, SDG12-Responsible Consumption and Production, SDG13-Climate Action, SDG15- Life on Land, Peace, SDG16-Justice and Strong Institutions.
All the actions and activities performed in the island contribute to the improvement or worsening of education, health and culture. In fact, *environment* and *wealth* are the 2 main sustainability indicators to value the wellbeing of the island. *Environment* comprises of $C0_2$ concentration, coal use and forest condition. Conversely, wealth is evaluated through 5 categories of elements: sources of income, transfers, savings, private buildings (large or small houses) and public buildings (e.g., university, health centers, theaters, schools).

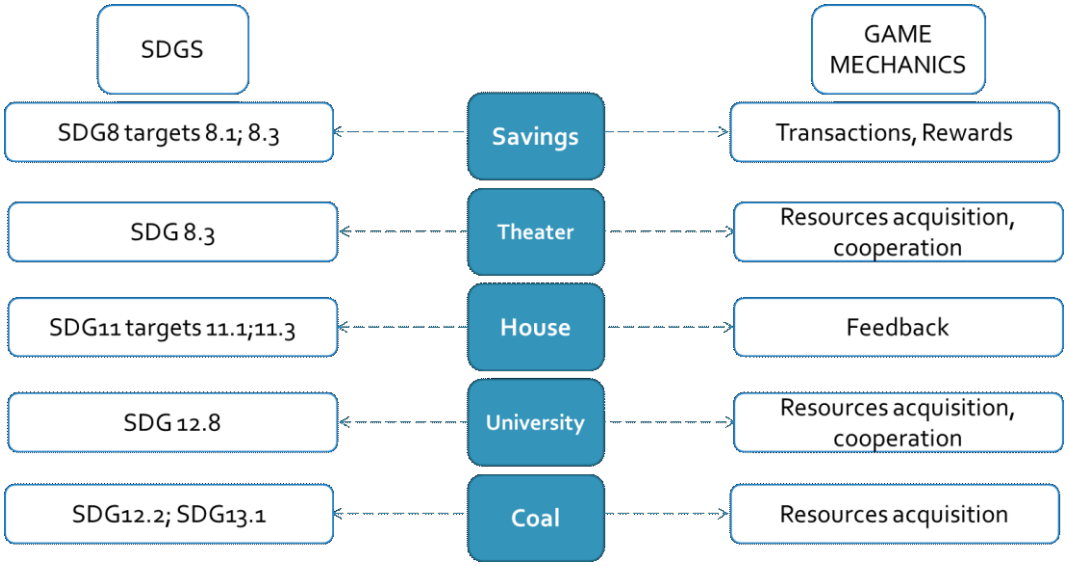

Figure 48_Application of analytical flow chart in New Shores for identifying connections between targets' goals and game mechanics

Figure 48 shows the application of the analytical flow chart with the aim of identifying connections between targets of covered SDGs and game mechanics. *Housing* is the only one that holds connections with SDG 11. For this reason, it will be better discussed in the second phase of the analytical flow chart. According to

game mechanics, *housing* provides feedback, as it shows information regarding the player's performance, in particular through the number of houses built on the island. Otherwise, elements have connections with SDG 8- Decent Work and Economic Growth, SDG 10- Reduced Inequality, SDG 12- Responsible Consumption and Production and SDG 13- Climate Action.

Universities present connections with SDG 10 and target 12.8 - "By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature". This is possible because universities are the place in which education takes place, including perhaps education for sustainable development (including climate change education) through teacher education and student assessment (sdgs.un.org/goals/goal12). In *New Shores*, universities are collectible items (as resources acquisition) and are realized through the cooperation among players (investing money).

Theatres are connected to SDG 8 through target 8.3 – "Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services". The theatre's construction offers new jobs, a higher level of welfare and a good use of resources to invest in the island. Like universities, they are collectible items and they are the product of the collaboration among the players.

The only type of natural resource available on the island is coal. The use of coal shows relations with SDG 12 and SDG 13, especially target 12.2 – "By 2030, achieve the sustainable management and efficient use of natural resources" and 13.1 – "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries". In *New Shore Island,* hurricanes and floods are frequent natural disasters. Players must pay attention to the massive use of coal extraction at the expense of forests that instead, protect and defend houses and public buildings from hurricanes. These elements denote resource acquisition in game mechanics. Savings allow players to build structures, which makes them connected to SDG8, in particular target 8.1 – "Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries" and target 8.2 – "Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors". In the context of game mechanics, savings comprise of transactions of direct trading between players and the acquirement of rewards earned due to beneficial actions performed or achievements gained throughout the game.

As mentioned in the outcomes of the classifications, SDG 12 is one of the most frequently discussed objectives in games, reason why it will be thoroughly analysed in the analytical flow chart.

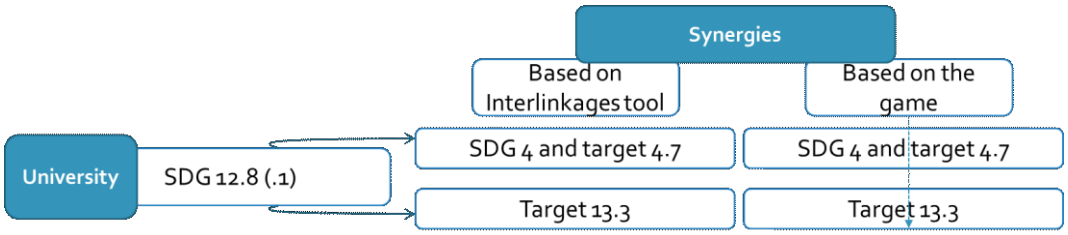

Figure 49_ Specific application of the analytical flow chart for "University" in relation to SDG11targets and indicators

The outcomes of *Figure 49* show the purpose of the analytical flow chart in university, observed in target 12.8. According to the *Interlinkages* visualization tool, a target can imply positive linkages with SDG 4- Quality Education and SDG 13- Climate Action. Universities are the place where inclusive and equitable quality education must be ensured and lifelong learning opportunities must be promoted for all. For such reasons, universities fit perfectly into target 4.7- "ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development". The game element of university in *New Shore* contributes to the improvement or worsening of education and level of culture of the island's inhabitants.

6.2 Second test on serious games developed for the Talenti Polito challenge

In the following sections the analytical flow chart will be applied to better analyse the game elements designed and implemented by the students.

Table 24_Comparative analysis among the serious games of the second test

Serious games	*Genre*	*Type and availability*	*Target Audience*	*Before/after SDGs establishment*	*SDGs*
Patent	Education	Online and Free	General Audience	After (2020)	SDG6 SDG7 SDG9 SDG11 SDG12 SDG13

Polinks	Education	Online and Free		General Audience	After (2020)	SDG6 SDG7 SDG9 SDG11 SDG12 SDG13 SDG17
iPolito	Education	Online and Free		General Audience	After (2020)	SDG4 SDG6 SDG7 SDG9 SDG11 SDG12 SDG13 SDG17

This second test of the flow chart is used to assess how the students designed their sustainable projects and how they created respective interlinkages. Although in Chapter 4 the analytical diagram was used to analyse the game elements identified "by playing", in this chapter the elements are seen in the "by making" context. Out of the 4 games that were analysed in the interviews, only 3 will be used for testing the flow chart. The fourth ranked game, *4…3…2…1…Sustainability*, will not be taken into consideration due to the lack and inconsistency of the collected data.

6.2.1 Application for Patent

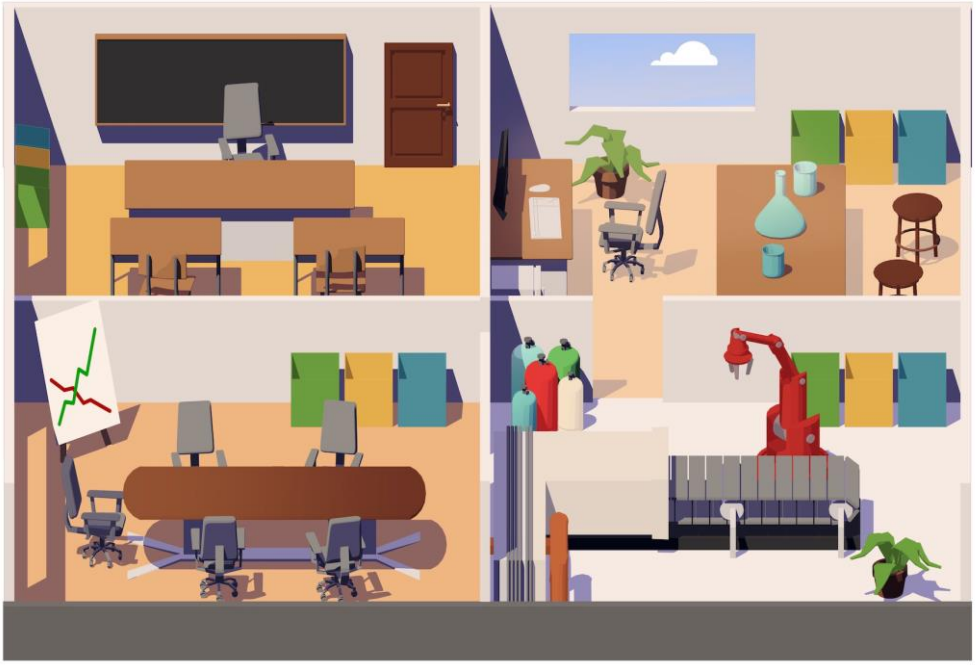

Figure 50_ Four areas for developing projects (teaching, research, consultancy and realization)

The main game elements of *Patent* are respectively the *5 Department cards*, *6 Action card* and *32 Project cards* to be developed across the four areas *(Figure 50)*.

The first two packs of cards will not be taken into account for the analytical flow chart as, even though they precisely represent game mechanics, they are not associated to the SDGs. The deck of project cards, on the other hand, will be the subject of studies in the analytical flow chart. Even if all the project cards are considered resources attainment and rewards for game mechanics, the analysis is interesting for the purpose of SDGs assessments. The aim is to study which actions and projects the students of Group 1 have selected to address the SDGs. As emerged from the student's interview, the main SDGs addressed in *Patent* are: SDG 6- Clean water and sanitation, SDG 7- Affordable and Clean Energy, SDG 9-Industry, Innovation and Infrastructure, SDG 11-Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, and SDG 13-Climate Action.

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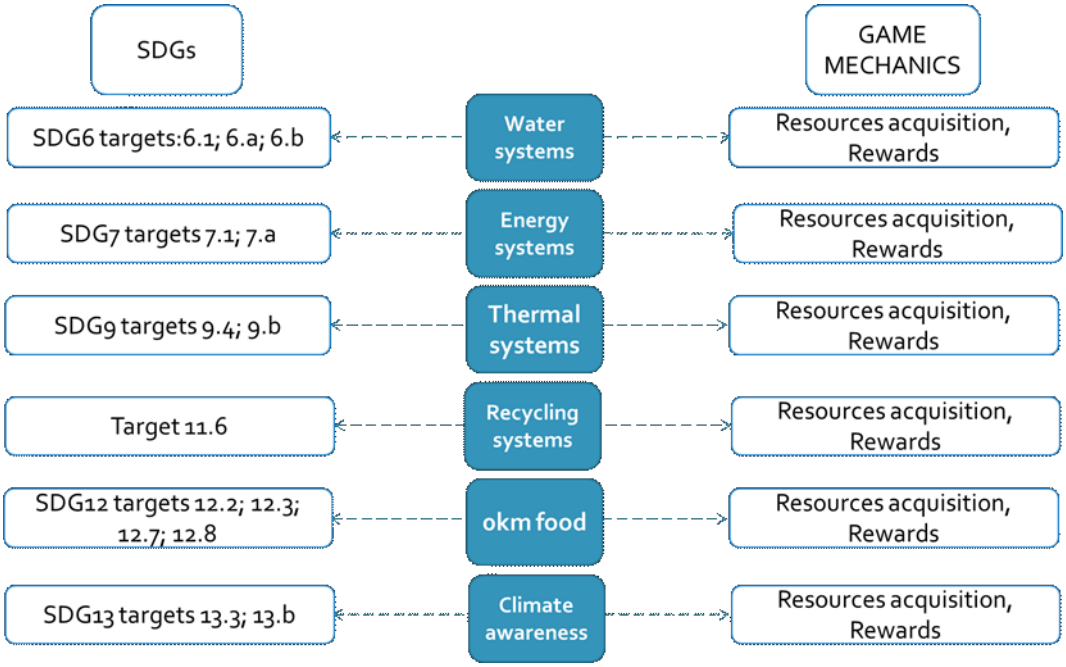

Figure 51_ Application of analytical flow chart in Patent for identifying connections between targets' goals and game mechanics

By observing the analytical flow chart (*Figure* ***51***), it is found that the projects accrued out in *Patent* are summarised in 6 main categories of game elements: water systems, energy systems, thermal systems, recycling systems, food km0 and climate awareness. They present explicitly connections with appropriate SDGs.

For instance, according to SDG 6 and targets 6.1, 6.a and 6.b, black water filter systems, rainwater collection systems or fog-catching nets are part of the group of water systems. For what concerns SDG 7 and targets 7.1 and 7.a, a decent number of systems have been implemented, including micro wind turbines, graphene batteries or photovoltaic panels and roof tiles. Solar thermal systems or geothermal

probes are some of the systems designed to heat and cool the campus based on SDG 9 and targets 9.4 and 9.b. Many other sustainable initiatives relate to SDG 12 and targets 12.2, 12.3, 12.7 and 12.8, including 0 km food products and electronic recycling devices (such as RAEE recycler).
Other climate awareness initiatives have also been identified: promoting campaigns to raise individual awareness for SDG13 and targets 13.3 and 13.b, individual sustainable behaviour, such as the use of bioplastic cutlery, water bottles, electric bikes.
Finally, concerning SDG 11, specific projects have been designed to waste recycling systems and air quality improvement technologies, following target 6. They include: bioenergetic generators, electric bikes, eco compactors or smart grids. On the basis of the intention to better analyse SDG 11, it is possible to distinguish these projects by referring to the indicators of target 6, which are respectively: 6.1- "Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities" and 6.2- "Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)". The use of bioenergetic generators, compost and eco compactors refer to indicator 6.1, whilst CO2 eating bacteria and electric bikes refer to indicator 6.2. When applied, these techniques can improve the energetic performance of the campus. In addition, they also align with the characteristics and targets of SDG 11 and, furthermore, they implement positive or negative interlinkages with other SDGs. For instance, the game element of CO2 Eating Bacteria holds synergies with SDG 9 and SDG 12, as shown in *Figure 52*.
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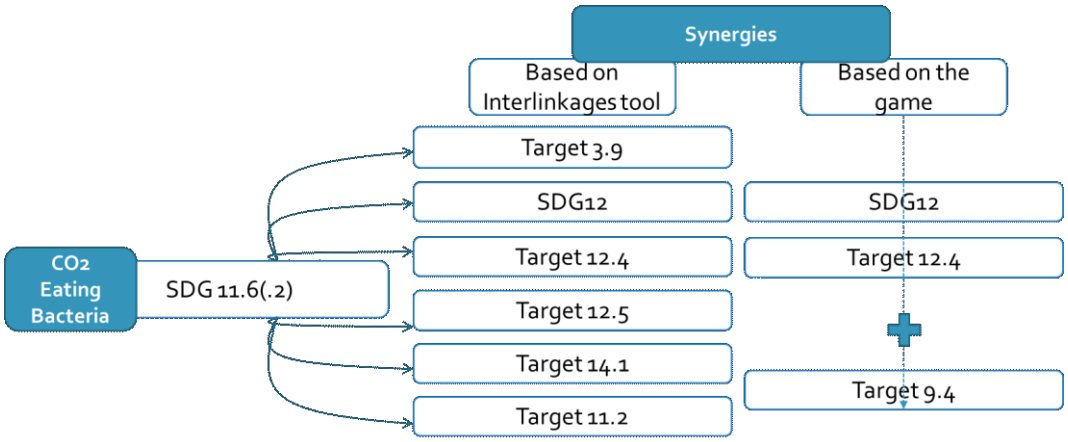

Figure 52_ Synergies of CO2 eating bacteria element in Patent

As explained in Chapter 3, the issue of the linkage between goals is addressed by the JRC in the development and use of their *"Interlinkages" tool*. Such tool proves very useful in identifying the effects that developed projects may have on other goals. According to the *Interlinkages tool*, target 11.6 can have synergies with SDG

3, SDG 12 and SDG 14. The case of project *Co2 Eating Bacteria* in fact shows that its development could have positive effects on target 12.4 and also on SDG 9 for target 9.4, by increasing resource-use efficiency and by improving the adoption of clean and environmentally sound technologies.
Among the projects listed above, *Eco compactor* also has positive effects on SDG 12 and SDG9 with the addition of target 12.5, referring to waste reduction as shown in *Figure* ***53***.

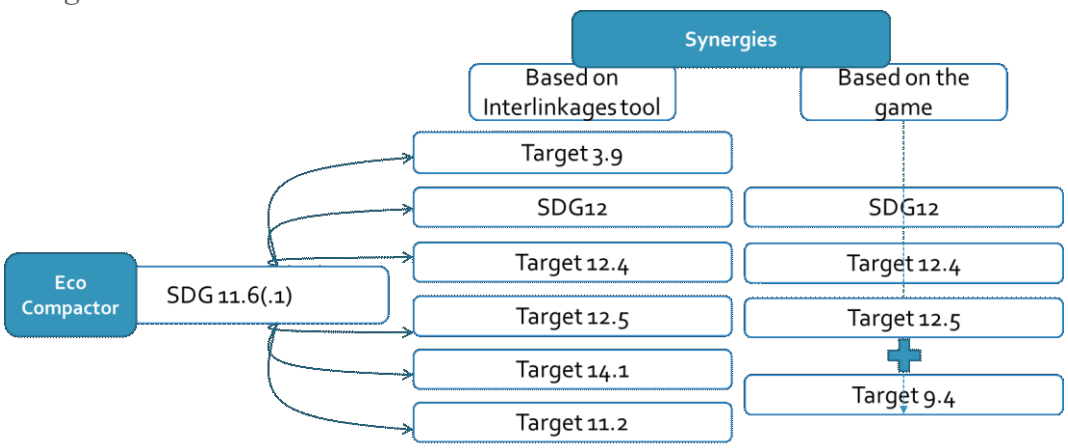

Figure 53_ Synergies of Eco Compactor element in Patent

6.2.2 Application for Polinks

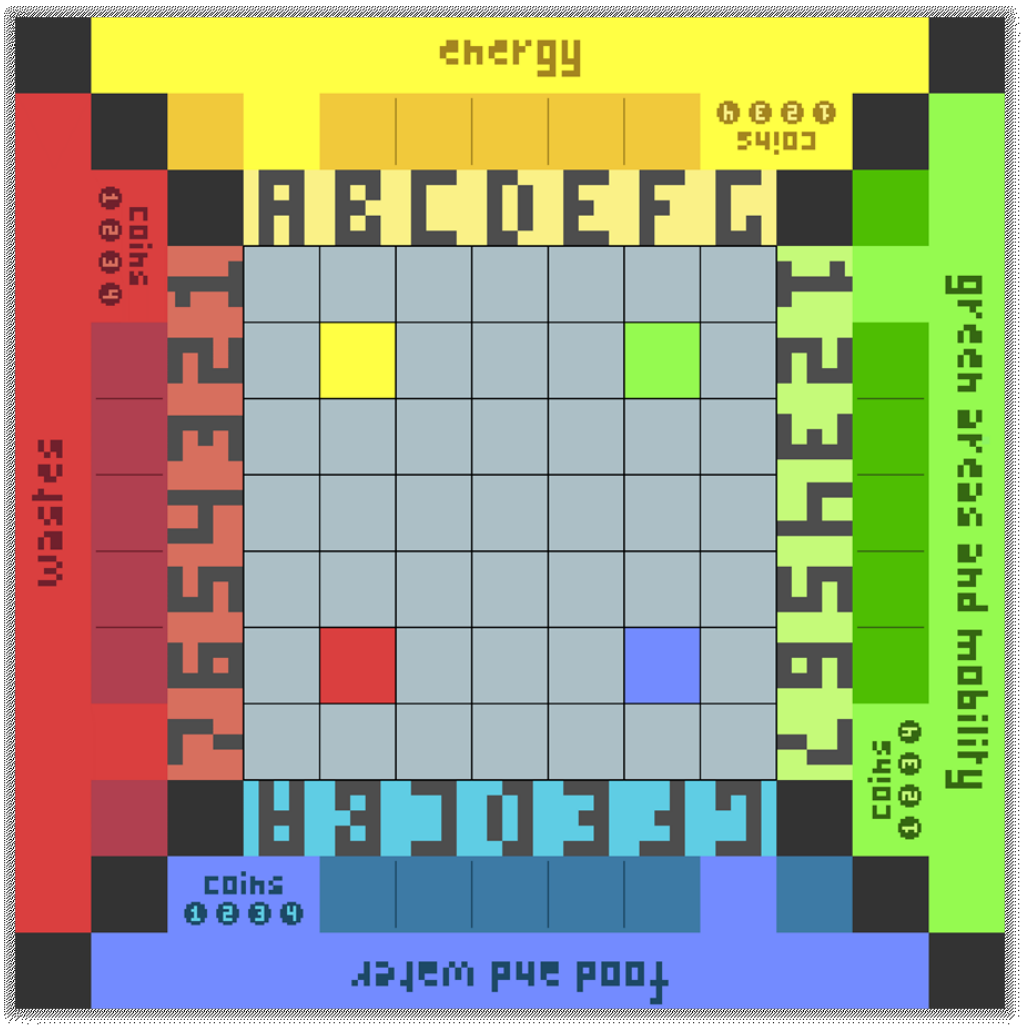

Figure 54_ Polinks game table organized according to 4 areas: food and water, wastes, energy, green areas and mobility

Polinks mainly consist in 4 different of card decks: transport and green areas, water and food, waste and energy. An additional deck, the "give and take", contains the contingencies and probabilities that may occur during the course of the game. All these decks are employed in the analytical flow chart. According to game mechanics, the 4 main decks that contain the players' probable projects and actions, identified as the attainment of resources and/or rewards. The desk of "give and take" is instead identified as transaction because they involve trading between players, directly or through intermediaries.

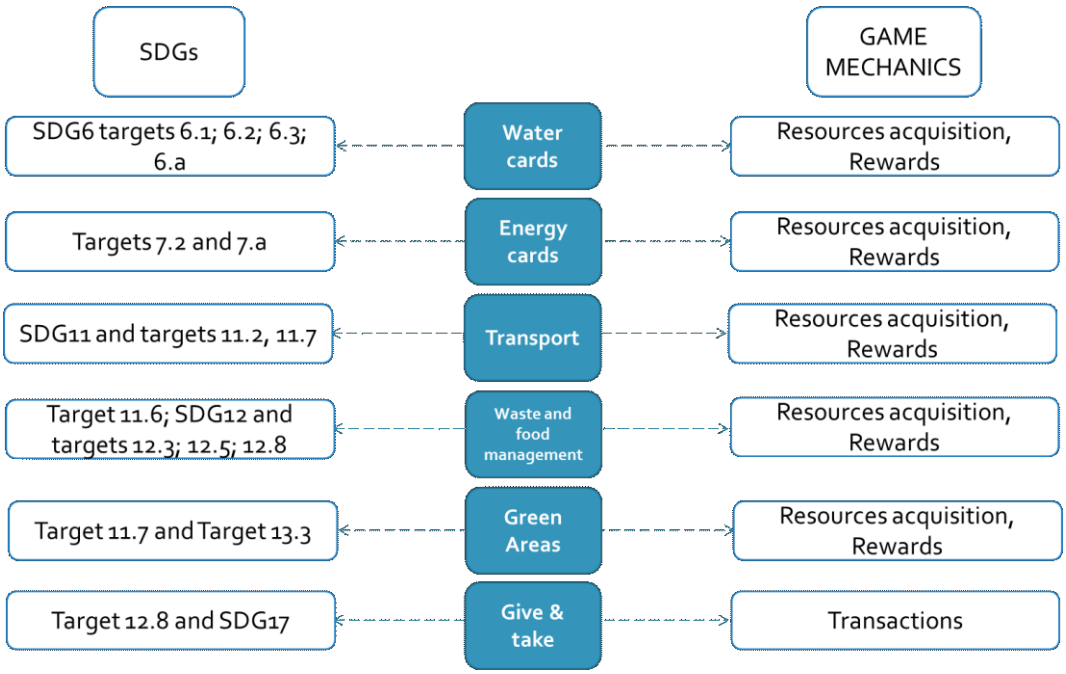

Figure 55_ Application of analytical flow chart in Polinks for identifying connections between targets' goals and game mechanics

According to SDGs, the students' interviews have showed that the main SDGs addressed in *Polinks* are: SDG 6-Clean water and sanitation, SDG 7-Affordable and Clean Energy, SDG 9-Industry, Innovation and Infrastructure (less addressed), SDG 11-Sustainable Cities and Communities, SDG 12-Responsible Consumption and Production, SDG 13-Climate Action, and SDG 17-Partenerships for the goals. As shown in *Figure 55*, the main sustainable actions that players can do are summed up in 6 main groups. Water cards, which refer to SDG 6 and in particular to targets 6.1, 6.2, 6.3 and 6.a. are developed by group 7. Some of the projects that concern sustainable management of water and sanitation for all, include rainwater tanks and filtering treatments, sinks with photocells and water supply points where students can refill their water bottle. In regards of SDG 7, the projects developed for the campus relating targets 7.2 an 7.a, such as photovoltaic windows, bike energy storage, water filtering systems, classroom thermoregulation and benches with recycling bins. Particular attention is paid to food and waste management: SDG 11 and especially SDG 12 ensure sustainable consumption and production patterns through targets 12.3, 12.5 and 12.8. 0km food for the canteen, vegan weeks, recycling research workshops and rooftop vineyards are some of the initiatives concerning the targets mentioned above.

Moreover, green and public spaces are optimal to the improvement of the campus' sustainability. Starting up vegetable gardens, creating green walls and planting trees for every flight walked over, by staff and students, are some of the possible actions to contribute to fight against climate change according to targets 11.7 and

13.3. The last deck follows the "give and take" rule, involving different kinds of contingencies and possibilities as confirmed by interviewed students.
SDG 11 comprises of many positive interlinkages connected to most of the actions that can be undertaken in *Polinks*. Particular attention is given to transport systems and green areas, which are strictly related to targets 11.2 and 11.7.

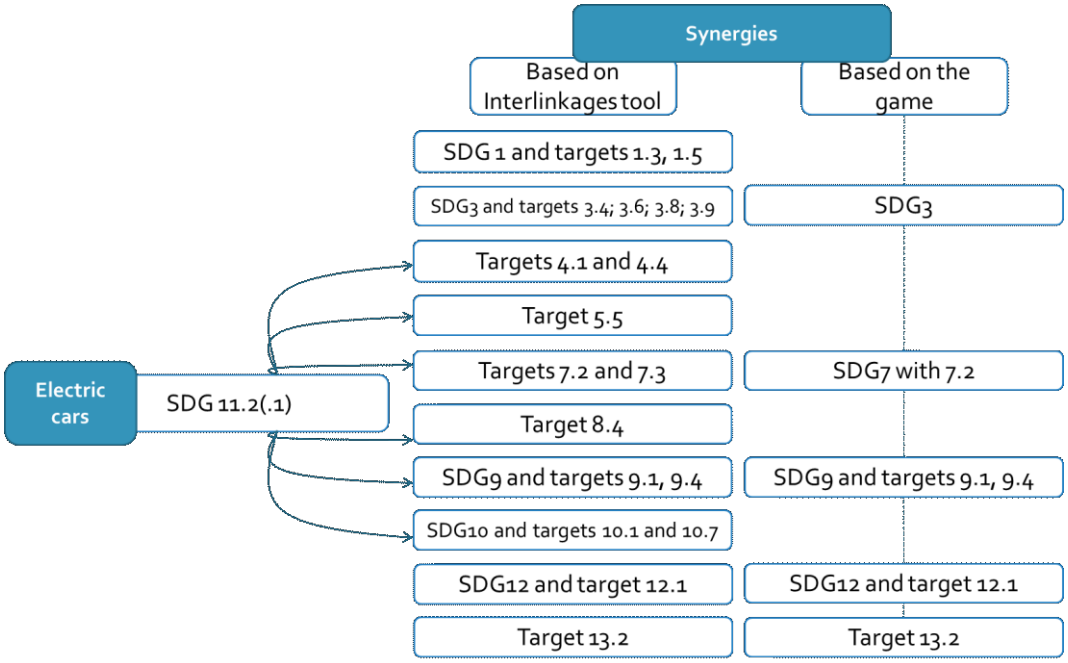

Figure 56_ Synergies of "Electric cars" element in Polinks

For what concerns transport systems, the game element of "electric cars" is analyzed based on synergies with other SDGs as shown in *Figure **56***.
According to the *Interlinkages* tool, target 11.2 can have synergies with SDG 1- No Poverty, SDG 3- Good Health and Well-being, SDG 4- Quality Education, SDG 5- Gender Equality, SDG 7- Affordable and Clean Energy, SDG 8- Decent Work and Economic Growth, SDG 9- Industry, Innovation and Infrastructure, SDG 10- Reduced Inequality, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action.
In the case of the electric cars designed for *Polinks*, it is possible to recognize some positive interlinkages in particular with SDG 3. This is because the choice of using electric cars over petrol- or diesel-powered cars ensures healthy lives and promotes well-being. Their use contributes to the reduction of CO2 emissions. In addition, electric cars develop and increase affordable, reliable, sustainable and modern energy. This perfectly addresses SDG 7, specifically 7.2 and 7.3. Among other sustainable initiatives and projects designed for *Polinks*, there is also the "Charging stations for hybrids and electric vehicles" card. Consequently, facilitating and encouraging players to choose electric cars, while also enhancing the use of

renewable energy through the "photovoltaic panel" card. This last element is also in line with target 12.1 for the employment of a framework of programmes on sustainable consumption and production patterns. As confirmed by interviewed students, many synergies are found among initiatives and projects in *Polinks*.
SDG 9 includes electric cars, which play a crucial role in ensuring sustainability as they promote inclusive and sustainable industrialization and also foster innovation. Their use contributes to develop quality, reliable, sustainable and resilient infrastructure, to support economic development and human well-being. According to target 9.4, the production of electric cars follows the directives that aim to increase resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, in accordance with their respective capabilities. The implementation of electric systems involved the campus in the establishment or operationalization of an integrated strategy which increases their ability to adapt to the adverse impacts of climate change, according to target 13.2.
Furthermore, an interlinkage with transport systems, referring to target 11.7 can be represented by the game element of "Experimental backyard vegetable garden". According to the *Interlinkages* tool the only synergy with target 11.7 is held in SDG 10. In *Polinks*, the game element analysed presents positive connections with other SDGs and they are SDG 3- Good Health and Well-being, SDG 4- Quality Education, SDG 5- Gender Equality, SDG 8- Decent Work and Economic Growth, SDG 10- Reduced Inequality and SDG 12- Responsible Consumption and Production (*Figure 57*).

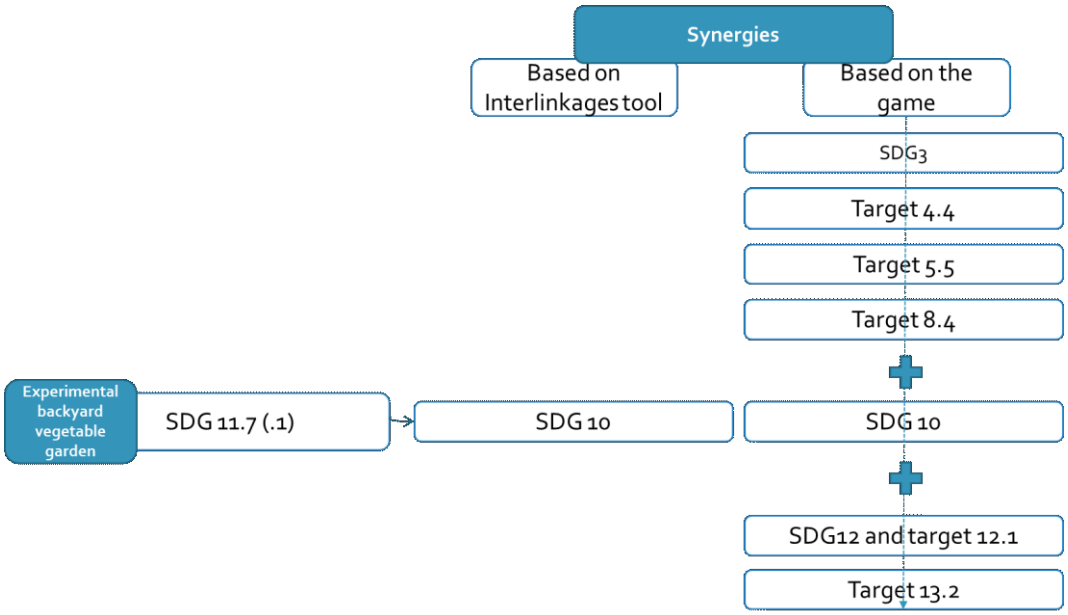

Figure 57_Synergies of "Experimental backyard vegetable garden" element in Polinks

The synergy with SDG 10 can be identified in guaranteeing the activity the shared management of the experimental vegetable garden between all the users of the campus, without any distinction in terms of gender, age or disability. The experience of the experimental vegetable garden empowers and promotes social and economic inclusion of all according to target 5.5.
The remaining synergies refer to the opportunity to ensure healthy lives and promote well-being (SDG 3) or to increase the number of youth and adults who have relevant skills, including entrepreneurship, technical and vocational skills in the field of sustainable 0km agriculture (target 4.4). Finally, based on target 8.4, this activity progressively improves resource efficiency in consumption through a controlled production, avoiding waste (SDG 12 and target 12.1).

6.2.3 Application for iPolito

Figure 58_Complete game set for physically playing iPolito

iPolito is a competitive card game mainly composed of 5 different decks of cards: "decision cards", "objective cards", "strengthening cards", "unforeseen cards", "multiplayer decision cards" (*Figure **58***). Only the decks that contain decision and strengthening cards refer to SDGs and they will be used for the analytical flow chart. According to game mechanics, the main 4 decks of cards that include projects and actions to be taken by the players are identified as resources acquisition and rewards. The other 3 decks respectively refer to the game mechanics below: "objective cards" are Win State since their related concepts make one player or group the winner-draw; "unforeseen cards" are elements of randomness namely chance; finally, "multiplayer decision cards" comprise of trading between players, which occur directly or through intermediaries defined in the literate as *transactions* (Werbach and Hunter, 2012).

On the other hand, from the point of view of sustainability, as can be seen in *Figure **59***, the SDGs most heavily treated in iPolito were respectively: SDG 4- Quality Education, SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 9- Industry, Innovation and Infrastructure, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action and SDG 17- Partnerships to achieve the Goal (lesser-covered goal).

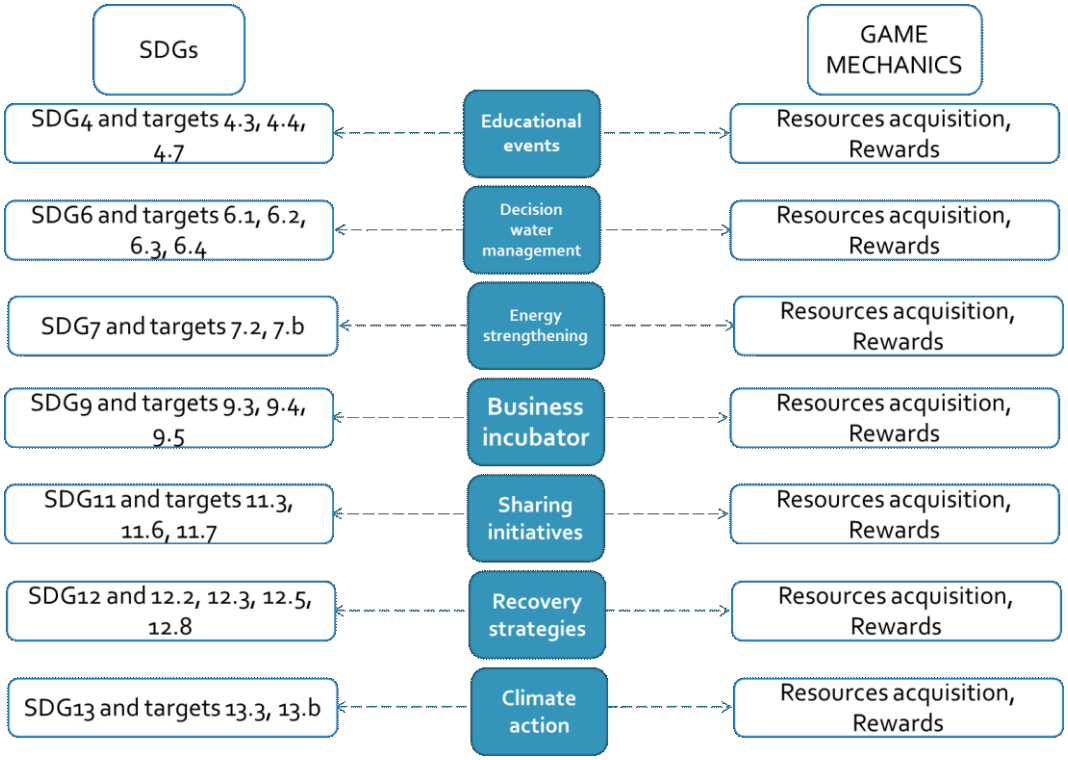

Figure 59_ Application of analytical flow chart in iPolito for identifying connections between targets' goals and game mechanics

The main game elements of *iPolito* can be summarised in 7 main categories of interventions, strategies and project to execute in the campus. Moreover, they were also condensed according to the goals they refer to. In terms of game mechanics, however, all categories are recognizable in resource acquisition: by acquiring useful or collectible items, coins or sustainability points; and in rewards: by receiving bonuses for actions, projects and initiatives carried out during game sessions.

Otherwise, in terms of SDGs, some interesting connections can be explored in more detail. Many educational events, such as sustainable weekends to raise awareness, projects with Talents and online informative courses refer to SDG 4 and targets 4.3, 4.4. Through these activities, the common aim is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all learners. In particular, those activities ensure students to acquire knowledge and the skills required to promote sustainable development according to target 4.7.

Further, the topic of water management is tackled through cards that refer to SDG 6 and specially to targets 6.1, 6.2, 6.3 and 6.4. The cards designed by group 4 involved many projects and proposals such as water fountains inside the campus to fill “Polito bottles”. The fountains collect rainwater system and the River Po’s water, filtering it and distributing it as drinkable water.

In SDG 7, the projects designed for the polytechnic campus concern targets 7.2 and 7.b, such as crystalline silicon photovoltaic panels, light ignition sensors, external

thermal insulation, the initiative of “M’illumino di meno” (I light up less)[36], low enthalpy geothermal plants and centralized air conditioning.
Business incubators, such as *Living Lab*, enable studies and researches leading to patents and projects with companies outside the university. Through these devices, special bacteria species are used, which can degrade plastic, or even capture CO2, as was executed in the CCU project (Carbon Capture Utilization). These initiatives respond especially to SDG9 and targets 9.3, 9.4 and 9.5strong synergies with SDG 13. In *iPolito*, SDG 11 refers instead to initiatives that promote students to adopt more virtuous behaviour on campus. Carpooling, car sharing, bike rental services, green roofs (“Orti Alti” project), organic bottles and lunchboxes are only some of the numerous proposed actions that answer targets 11.3, 11.2 and 11.7.
The most interesting synergies that have emerged between different actions of the game involve SDG 12. Such synergies are in fact very frequent with SDG 6 (e.g., rainwater collection system), SDG 8, SDG 9 and SDG 13 (e.g., BiosPHera 2.0, CCU- Carbon Capture Utilization), SDG 4 and SDG 11 (e.g., Conferences on the impact of food on the environment, internal short educational game).
Moreover, climate actions have interesting relevance both in terms of initiatives and synergies with other goals. Examples include appropriate courses on climate change issues, *Talent* projects initiatives, bicycle awareness campaigns, electric car charging stations, and research on bacteria that capture CO2. Finally, SDG 17 is a minor goal because generally it is already addressed among the cards, the players and game mechanics.

[36] "M'illumino di meno" is the Caterpillar (Rai Radio 2) programme's initiative on energy saving and environmental awareness. The Politecnico di Torino has been taking part for years by offering a programme with in-depth discussions on energy transition issues and the now traditional "kWh hunt" flash mob, together with the universities of the Network of Universities for Sustainable Development (RUS) (https://www.campus-sostenibile.polito.it/it/m_illumino_di_meno).

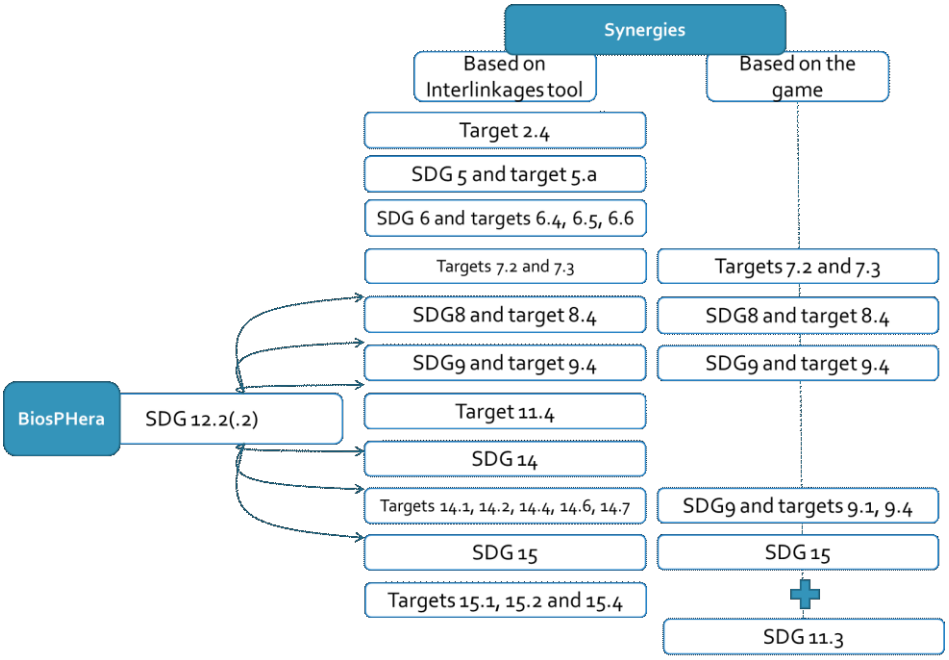

Figure 60_ Synergies of "BiosPHera" element in iPolito

In *iPolito* the SDGs most addressed in projects, initiatives and actions are SDG 9 and SDG 12. The topic of sustainable cities and communities is only partly analysed and reflexively based on the implementation of certain actions during the game sessions. For this reason, it will be explored in depth using projects valued in the analytical flow chart. These projects do not deal directly with SDG11 but address it through synergies with other goals.

BiosPHera is one of the analysed projects and consists in a self-sufficient energy housing module. The *BiosPHera*'s synergies are described in *Figure* ***60***. *BiosPHera* is a project which tackles target 12.2, whilst also holding synergies with: SDG 2- Zero Hunger, SDG 5- Gender Equality, SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 8- Decent Work and Economic Growth, SDG 9- Industry, Innovation and Infrastructure, SDG 11- Sustainable Cities and Communities, SDG 14- Life Below Water and SDG 15- Life on Land.

The element of *BiosPHera* holds particular similarities with targets 7.2 and 7.3: due to its autonomy, it runs on renewable and sustainable energy. The use of available resources is constantly monitored especially for domestic material consumption (target 8.4). Moreover, *BiosPHera* is also resilient and unfractured, with the ability to promote inclusive and sustainable industrialization and foster innovation, according to SDG 9. In particular, it can reduce consumption in terms of CO2 as specified in target 9.4, through the adoption of clean and environmentally sound technologies. Furthermore, as its construction does not involve land consumption, some synergies can also be found with SDG 15. Therefore, an extra positive interlinkage is recognizable in SDG 11, especially focusing on target 11.3 to support

inclusive and sustainable urbanisation. According to the *Interlinkages* tool, target 11.2 could also have 2 negative links with targets 2.4 and 11.6. In this case, *BiosPHera* does not have links with these 2 targets neither in a negative or positive way.

Another interesting element to be analysed is that of Carbon Capture Utilization-CCU. The analytical flow chart in *Figure* ***61*** shows that CCU is recognizable in target 9.4, according to the aim of adopting clean and environmentally sound technologies. Based on the *Intelinkages* tool, target 9.4 has synergies with SDG 1- No Poverty, SDG 2- Zero Hunger, SDG 4- Quality Education, SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 8- Decent Work and Economic Growth, SDG 10- Reduced Inequality, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action, SDG 14- Life Below Water, SDG 15- Life on Land and SDG 17- Partnerships to achieve the Goal. Otherwise, CCU positively responds to certain targets only. Among the synergies recognizable in CCU, some address SDG 7 and target 7.2 to increase the share of renewable energy. According to target 8.4 and 11.6, CCU contributes to programmes on sustainable consumption and production by paying particular attention to air quality, reusing CO_2 from industrial waste.

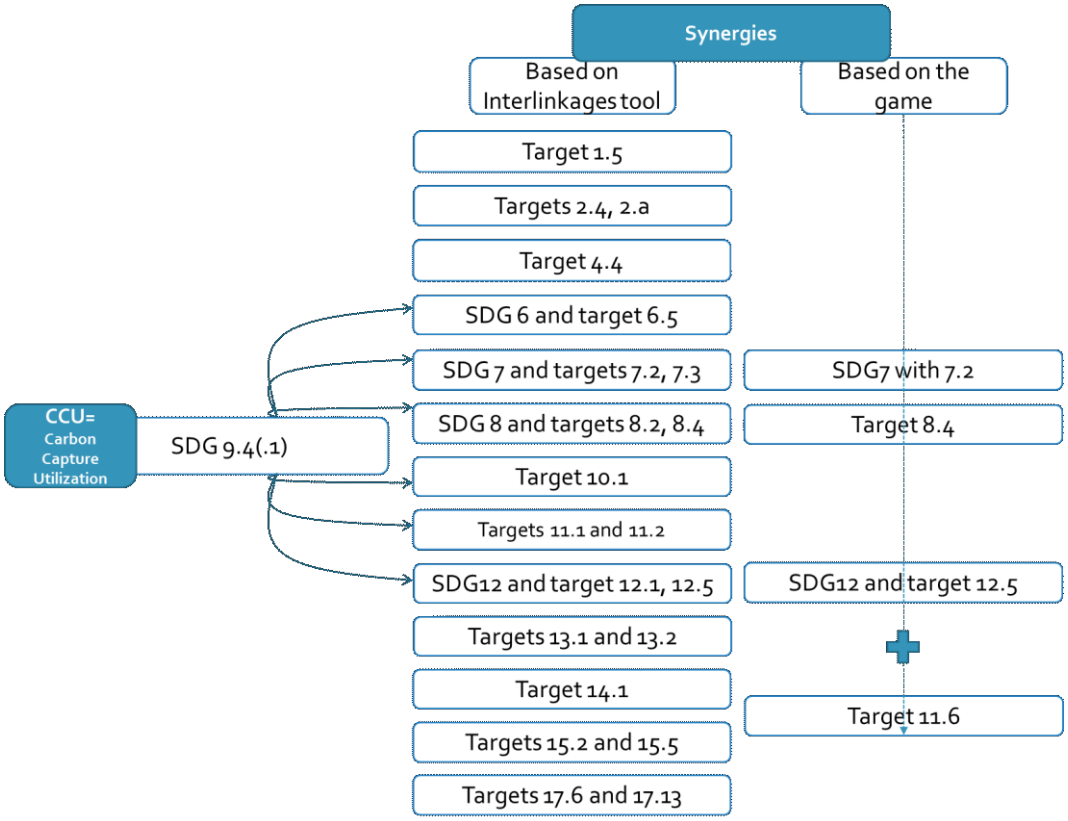

Figure 61_ Synergies of "CCU" element in iPolito

Finally, other synergies are found in SDG 12 especially in target 12.5 which aims to reduce waste through prevention, reduction and recycling and the reuse of material. Even though, according to the *Interlinkages* tool, target 9.4 might have negative impacts on other goals, the use of CCU does not foresee any according to those identified. However, these would be linked to the targets 1.3, 2.2, 3.4 and 3.8, 4.1, 5.4 and 5.5, 6.5, 8.5, 10.7, 14.4, 16.4 and 16.6 and finally 17.11.

6.3 Overall discussion

In this chapter, the results of the first applications of the analytical flow chart have just been described. This trial involved six serious games, the first three resulting from a classification of 67 sustainable games and the last three from a university challenge that saw 59 students as developer protagonists. The first three games were *Energy City*, *Urban Climate Architect* and *New Shore: a game for democracy* and they were selected from the new classification described in Chapter 4. Moreover, the last three games, *Patent Polink* and *iPolito*, were all developed within *Talenti Polito Challenge* in the 2019/2020 academic year.

The proposing flow chart outlines a twofold objective: firstly, it identifies the game elements that transfer the SDGs' knowledge through game mechanics and, secondly, to recognise possible synergies or trade-offs among other goals.

The discussions on the results of the first trials of the flow chart therefore focus on game elements and how these respond to the SDGs. The considerations concerning game elements, are mainly divided according to indicators, game mechanics and SDGs addressed in games.

Indicators are very common elements in serious games, and usually they express and show the progress of the player's performance, and of the course of the game itself. Based on this definition, in the analysed games the indicators illustrate increases and decreases in values referring to the environmental, housing, social and economic domains. According to the environmental some of the indicators represent air quality or CO_2 emissions, as occurs in *iPolito* and *Energy City*. In alternative, in games such as *Urban Climate Architect* and *New Shore: a game for democracy,* indicators can also illustrate environmental impacts, the use of natural resources and temperature level. The domain of housing and social care is generally represented based on the percentage of built houses, realised offices and constructed buildings as transpires from *Energy City*, *Urban Climate Architect and New Shore: a game for democracy*. In addition, indicators for money, budgets and savings that refer to economics, help players manage their finances and planning initiatives within all the analysed games.

On the other hand, by analysing the game elements from the point of view of game mechanics, it is possible to make two macro distinctions: either through indicators or through projects/actions/initiatives to be carried out within the serious game. Indicators tended to be represented in the analysed games through feedback (information about how the player is doing) and win states (objectives that make one player or group the winner-draw and loss states are related concepts). Instead, projects, actions and initiatives were designed and implemented in the games through resource acquisition (obtaining useful or collectible items), rewards (bonuses for some actions or achievements), feedback (information on the player's performance) or win states (objectives that make a player or group the winner and loss states are related concepts).

Finally, the last considerations concern SDGs. The identification of SDGs addressed in serious games has been found based on the illustrations of game elements such as sustainable actions, energy projects, green interventions or general improvements. For this reason, as emerged from the 6 serious games examined, the most investigated SDGs are SDG 11-Sustainable cities and communities, SDG 12-Responsible consumption and production, SDG 13- Climate action and, to a lesser extent, SDG 7-Affordable and clean energy and SDG 6-Clean water and sanitation. In particular, they have been respectively investigating the serious games as follows:

i. in Energy City SDG 7- Affordable and Clean Energy, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, and SDG 13- Climate Action;
ii. Urban Climate Architect SDG 6-Clean Water and Sanitation, SDG 8-Decent Work and Economic Growth, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, and SDG 13- Climate Action;
iii. in New Shore: a game for democracy SDG 8- Decent Work and Economic Growth, SDG 11- Sustainable Cities and Communities, SDG 12-Responsible Consumption and Production, and SDG 13- Climate Action;
iv. in Patent SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 9- Industry, Innovation and Infrastructure, SDG 11-Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, and SDG 13- Climate Action;
v. in Polinks SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 11- Sustainable Cities and Communities, SDG 12-Responsible Consumption and Production, SDG 13- Climate Action, and SDG 17- Partnerships to achieve the Goal;
vi. in iPolito SDG 4- Quality Education, SDG 6- Clean Water and Sanitation, SDG 7- Affordable and Clean Energy, SDG 9- Industry, Innovation and

Infrastructure, SDG 11- Sustainable Cities and Communities, SDG 12- Responsible Consumption and Production, SDG 13- Climate Action, and SDG 17- Partnerships to achieve the Goal.

Figure 62 shows the main findings of the SDGs addressed in the serious games analysed.

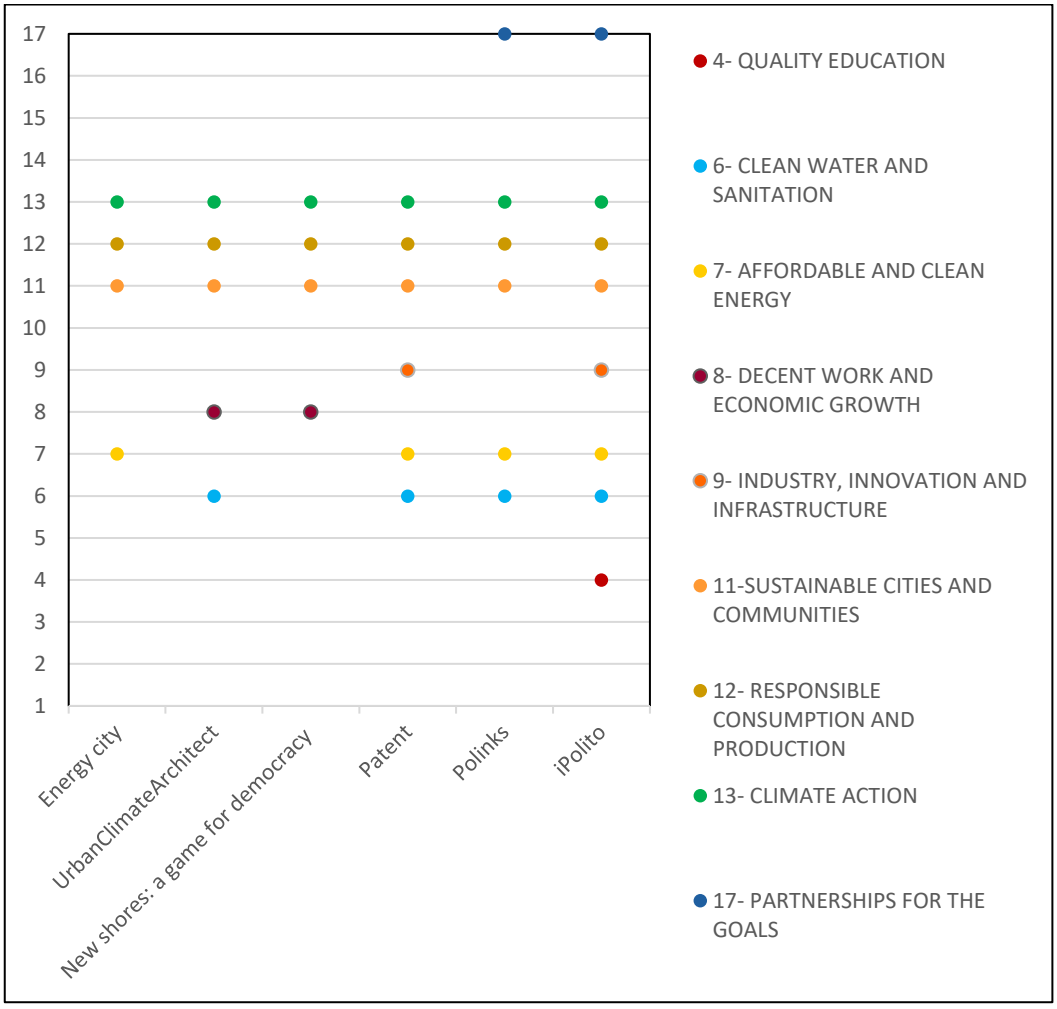

Figure 62_Synthesis of the main findings of SDGs tackled in serious games

The analysis of the flowchart, has allowed to highlight all the SDGs dealt with through the game elements and thus the respective game mechanics. At this point, according to the characteristics of the game, projects/actions/initiatives also played a decisive role in responding to targets of SDG 11 and SDG 12. What emerged from the study is indeed that the most commonly addressed targets in those actions and projects are: 11.3- By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries (in 4 out of 6 games), 11.6- By 2030, reduce the adverse per capita environmental impact of cities, including by paying special

attention to air quality and municipal and other waste management (in 4 out of 6 games), 11.7- By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities (in 3 out of 6 games), 11.1- By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums (in 2 out of 6 games) and 11.2- By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons (in 1 out of 6 games).

With regards to SDG 12, the projects/actions/initiatives developed in the serious games concerned the following targets: 12.2- By 2030, achieve the sustainable management and efficient use of natural resources (in 4 out of 6 games), 12.8- By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and live a harmonious lifestyle respecting nature (in 4 out of 6 games), 12.3- By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses (in 3 out of 6 games), 12.5- By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse (in 1 out of 6 games) and 12.7- Promote public procurement practices that are sustainable, in accordance with national policies and priorities (in 1 out of 6 games).

The latter and last considerations of the flow chart concern interlinkages among SDGs. Through these further analyses, interesting correlations emerged between the SDGs by using the *Interlinkages tool*. The synergies and trade-offs are also contained within actions, strategies, projects and initiatives that are developed in games. The *Interlinkages tool* is a valid and well-established instrument to identify possible connections between goals and targets because it is based on literature. Clearly, those connections can be confirmed or denied according to the features of each project/action/initiative. In fact, it was fascinating to study examples of game elements to realise that it is necessary to add new links to other targets or goals. An interesting scenario would be to investigate other possible uses of this flowchart based upon these preliminary considerations. For instance, can the analytical flow chart be used in a reverse way to build new games and define new synergies? The outcomes show that this flow chart could be a valid starting point for analysing both existing serious games and new sustainable serious games. Among the possible further developments, the use of the flow chart could be worthwhile to design and realize appropriate games to increase knowledge of sustainability challenges.

Chapter 7

Conclusions and further developments

This is the last chapter of the thesis. In this investigation, the primary aim was to assess the use of serious games as learning tools for spreading knowledge on sustainable development. These last few paragraphs summarise the macro-steps that have characterised the research of this thesis. The key concepts that have been analysed will also be revisited through the research questions to which I have tried to give answers. This chapter is divided into 3 sections: summary and remarks, key findings and limitations, and future developments.

Within the summary and remarks section, the research topics covered such as smart cities and sustainable developments are taken up again. In fact, the latter has been deepened from an educational and evaluative point of view through the analysis of SDGs and interlinkages. All these themes have found a meeting point in the study and application of serious games. These are the main object of all the analyses and research carried out, which will be presented in the section dedicated to key findings. The results of the new classification, the Challenge experience and the analytical flow chart tests will be reported accordingly.

The new classification has made it possible to take a snapshot of the situation of sustainable serious games made between 2007 and 2018, and still being played. The results of this new classification showed links between the SDGs, some of them obvious and others less so. This gave rise to the desire to further investigate which

SDGs the serious games focus on most and how such SDGs are interconnected. This led to the Challenge experience, in which 59 students were asked to design and implement sustainable serious games that directly addressed the SDGs. This educational experience produced interesting results, which were collected in various ways, including questionnaires and interviews. Among the results collected, there also those related to the application of the analytical flow chart. This flow chart was defined firstly in order to identify the SDGs addressed in the games and secondly to categorize possible connections and relations among SDGs. Through the applied flowchart tests, the functionality of the interlinkages tool was evaluated. Finally, in the last section, dedicated to future developments, possible scenarios for research and application of serious games in other educational contexts are suggested.

7.1 Summary and remarks: answering to the research questions

This study has identified the relevance of educational learning tools as serious games for emerging issues related to sustainable development. Nowadays, sustainability challenges have increased exponentially involving climate change, energy efficiency, sustainable consumption and production and smart cities and communities.

The development of sustainable smart cities is still at the centre of scientific debate. Population growth in cities is a current problem that has several implications on sustainability in terms of overcrowding, pollution, transport, energy, resources and services. As cities play a key role in the development of society, particular attention has also been paid to the definition of sustainable development goals. Formalised in 2015, the SDGs have the task of guiding all the countries of the world towards a sustainable transition that can give a future to the generations to come. Among these, SDG 11- Make cities and human settlements inclusive, safe, resilient and sustainable- is dedicated exclusively to “sustainable cities and communities”. For the first time, emphasis is placed on communities and the people who make them up. What is sought is the formation of intelligent communities, made up of individuals who are aware of the repercussions of their actions. Involvement and education are what is needed to raise people's awareness. People must feel that they are an active part of a project and must begin to be aware of their actions. For these reasons, it becomes necessary to educate and prepare them for change. Education for sustainable development supports this need and learning tools such as serious games can contribute to spreading knowledge among people.

In order to be able to investigate these issues properly, a number of research questions were defined at the beginning of this thesis in Chapter 1. The questions

were defined to guide the macro phases of analysis and study on serious games and sustainable development.
The main research question leading the whole work is, for ease of reference, given below:

How do serious games act as learning tools to convey sustainability concepts? And, more specifically*, how do serious games promote areas of knowledge and practice that relate to and encourage sustainable urban choices and behaviours?*

Through these chapters, it was clear that serious games were the main object of investigation in this work. Since they are described in the literature as educational tools capable of bringing benefits both from an educational and playful point of view, the decision was made to focus maximum attention on their capabilities. Such games, typically distinguishable by their dual purpose, are defined by some scholars as games for training or learning (Crookall, 2010). Serious games supply learners with an authentic experience in which enjoyment and learning seem to fit together perfectly (Gee, 2007; Prensky, 2003). Furthermore, they provide a varied scenario that fulfils their primary purpose of providing a risk-free environment for the active exploration of topical, intellectual and social issues, thus extending the use of gaming purely as an entertainment tool (Abt, 1987; Charsky, 2010; Katsaliaki and Mustafee, 2014). Hence, serious games can address sustainable development issues as an effective training and teaching tool for all those directly affected by the phenomenon, and especially, those who are called upon to explore and implement solutions to the problem, such as governments, academics, and policy makers (Katsaliaki, Mustafee and Kumar (2014); Katsaliaki and Mustafee, 2015). Addressing the complexity of sustainability necessitates significant changes in government policies, social and cultural values, public attitudes and behaviour. To facilitate these changes, in 2002 the UN declared the Decade of Education for Sustainable Development, 2005-14, promoting the key role of education in supporting people to meet the challenges of the present and the future (Fabricatore and Lopez, 2011). Teaching sustainability also calls for approaches and tools that support systemic thinking, and learning to deal with features of complexity, such as change, uncertainty and emergences. Due to their properties, serious games can be of great benefit for learning about complexity. They are also promising resources for safely and cost-effectively acquiring skills and attitudes (Gee, 2007). Furthermore, according to Bergeron (2006) learning via gameplay may be longer lasting and other studies, and it has been claimed that properly designing serious games can produce learning while engaging players (Prensky, 2006).

The level of engagement in serious games can be measured according to a number of characteristics ranging from game dynamics, game plots, challenges, achievements, character roles and even the accomplishment of the final goal. All these elements are linked within the game mechanics. In fact, it is the latter that governs the main actions of the games, defining the rules and also conveying the 'serious' messages to the players. Through game mechanics, grouped into 10 macro categories by Werbach and Hunter (2012), the dynamics of games are concretely realised. As described in Chapter 2, these are mainly: challenges, chance, competition, cooperation, feedback, resources acquisition, rewards, transactions, turns and win states. Furthermore, serious games also have generic components that are replicated and adapted across different categories. However, the specific mechanics of serious games have yet to be definitively identified and described. In this regard and according to Arnab et al. (2015), this is due to the greater complexity and less widespread use of serious games compared to traditional games. Serious games are quite varied in terms of features and can potentially provide different types of learning experience. It is therefore important to understand how different game elements can facilitate effective learning. With this in mind, an analytical flowchart was designed and proposed in this thesis. It was devised to explore firstly, through which game mechanics knowledge transfers take place and secondly, whether knowledge about sustainability is interlinked.

Serious games generally include all aspects of education - teaching, training and information - and are mostly available to all age groups (Michael and Chen, 2005). In addition, specific games can be proposed around a broad range of application areas, such as public policy, defence, management, health care, training, sustainability and education too (Zyda, 2005). Serious games have gained increasingly popularity as educational tools in educational contexts such as schools and universities, as a training aid for professionals and as a form of entertainment for all. A number of works confirm that such games help students enhance their awareness of the real world and understanding of educational course topics (Hirose, Sugiura and Shimomoto, 2004; Philpot et al., 2005).

In the specific case of this thesis, the players of interest are mostly university students. In fact, in the case of education, some studies report that it is the students themselves who prefer serious or simulation games to other classroom activities. Thanks to these games, they can improve their attitudes in a number of ways, which include economic, financial, work and personal (Livingston et al., 1973; Chin, 2009).

a) How can serious games be used with students to spread knowledge on sustainability issues?

Serious games can be used for different aims and applied in any contexts to achieve the objectives set. With regard to sustainability issues, the choice was made to focus on the target group of students and the educational environment, particularly that of university. Based on the desire to impart sustainable concepts through serious games, students should: know and understand the SDGs, learn the concepts of sustainable development, integrate the acquired notions into practical actions by changing attitudes and behaviours in everyday life (SDG Compass, 2015).
In particular, universities, as key agents in the process of transformation towards sustainability, have to dedicate themselves to promoting sustainable values in the students' community (Amaral and Martins, 2015; Albareda-Tiana et al., 2019). According to Prado et al. (2020) the teaching of sustainable development attempts to confront students with ethical issues in which they must decide what standards and codes society should develop to set human actions that seek greater economic well-being while supporting the natural environment too. Hence, students will have to assess and develop ethics behaviours for sustainability when deciding which resources to use for economic, social and environmental challenges, both in the classroom and in real life (Saitua-Iribar, Corral-Lage and Peña-Miguel (2020).
Recognized as essential agents in the transformation process towards sustainability, universities are committed to promoting professional skills and values to promote sustainable development (Miguel, Corral Lage, and Mata Galindez, 2020). The inclusion in the university curriculum of the promotion of sustainable development, the implementation of active methodologies in classrooms and the use of ICT, simulation tools and serious games, are essential to improve the theoretical and practical knowledge needed to promote such development (Area, Hernández and Sosa, 2016; Garrote, Arenas and Jiménez-Fernández, 2018; Li et al., 2019). Research is still ongoing on the application of serious games concerning sustainability. This is because there is currently no established consensus on the influence of serious sustainable games on students. The results available at the moment are inconclusive and much research is still in progress. However, it emerges that there is a positive relationship between the use of serious games and the topic of sustainability (Miguel, Corral Lage and Mata Galindez, 2020).
ESD, investigated in Chapter 3, is a transformative educational approach and as such supports research into sustainable development and recognises serious games as potential tools of involvement. In particular, it tackles the content and outcomes of active learning, pedagogy and the learning environment to move from teaching to learning and from an educational dimension to a transformational pedagogical one (Rondón, 2018). This way, ESD develops in both formal and informal institutions and extends from kindergarten to university. It is directly conceived of as education that occurs throughout life. Through this kind of approach, students can take action by collaborative, participatory and self-directed learning.

Furthermore, they are empowered and begin making conscious decisions without losing sight of economic, social and environmentally sustainable development (UNESCO, 2017; Edwards, 2018). In line with this, between 2005 and 2014, the promotion of changes in students' knowledge and behaviours was also supported by the United Nations. This interest subsequently led to the creation of the United Nations Decade of Education for Sustainable Development project (Gutiérrez, Benayas and Calvo, 2006; Miguel, Corral Lage and Mata Galindez, 2020). Bokova, Director-General of UNESCO, indicated that "A fundamental change is needed in the way we think about the role of education in world development, because it has a catalytic effect on the well-being of individuals and the future of our planet. [...] Now, more than ever, education is responsible for taking into consideration the challenges and aspirations of the 21st century, as well as promoting the right types of KPSS[37] that will lead to sustainable and inclusive growth, and to a peaceful life for all individuals" (UNESCO, 2017).

b) Which are the well-established methods or strategies to assess the effectiveness of learning by playing serious games?

Serious game applications seem to integrate the use of new technologies with game mechanics, so that people can express themselves through the actions of the games. Such games, unlike normal games, offer people, and therefore players, the opportunity to learn new things by playing. Tendentially, they are designed to be attractive and appealing to a broad target audience by meeting specific educational goals (Bellotti et al., 2013). These are some of reasons why they are called serious and therefore also learning tools by the scientific community (Von Wangenheim and Shull, 2009; Mouaheb et al. 2012; Emblen-perry 2018; Mueller et al. 2018). A number of researchers have recently given significant emphasis to the importance of learning assessment (Von Wangenheim and Shull, 2009; Kirkpatrick and Kirkpatrick 2006; Gentile 2011; Ouariachi, Elving, and Pierie 2018; Ouariachi, Olvera-Lobo, and Gutiérrez-Pérez 2018; Petri and Von Wangenheim 2016). As mentioned in Chapter 1 and subsequently taken up in Chapter 2, the evaluation of learning is a very sensitive issue in the scientific community (Hays, 2005; Enfield et al., 2012; Bellotti et al., 2013). This is because most studies do not adopt standardised practices for evaluating the educational effects of serious games. Consequently, a gap emerges to be filled and an opportunity for research. What has emerged from previous research is that there is a need to explore how to evaluate learning outcomes in order to explore how to design more effective serious games. Within the scientific community is widely accepted that the use of serious games generates positive effects on learning but some studies moderate this view and

[37] key professional skills for sustainability

suggest that while games have value in teaching and learning, their effectiveness in improving student performance is influenced by game design and specific educational purpose (Hays, 2005; Gee, 2007). Regarding this, in fact, game mechanics must be investigated, in order to understand which of them are the most suitable to achieve educational purposes. In this regard, the evaluation of serious games should also involve the evaluation of players' performance. Such assessment is significant because serious games are designed to support the acquirement of knowledge and/or the development of skills, hence their core system must be able to assess learning progress, as rewards and progress in the game must be carefully linked to it (Bellotti et al., 2013). Although further research is needed to establish the long-term results of games on student achievement and deeper learning (Young et al., 2012), there is initial evidence suggesting that games are able to engage and motivate learners who no longer find traditional approaches engaging (Wrzesien and Raya, 2010; Cheong et al., 2014; Nagle et al., 2014).

In order to better understand the learning impact of serious games, further tests are needed to evaluate the level of their success, evaluating whether the target audience achieved the defined objectives. Evaluation should cover both student learning, as well as the quality of elements, materials and resources that compose the instructional strategy (Branch, 2010). Empirical studies involve end users collecting data while applying the instructional strategy. Tendentially, this is carried out in form of surveys, case studies or experiments (Wohlin et al., 2012). According to Hevner and Chatterjee (2010), the objective of evaluation, models, methods, scales or frameworks can be used to carry out the research: i) a model consists of sets of propositions or statements expressing relationships between constructs; ii) a method is sets used to perform tasks; iii) a framework is used to serve as a real or conceptual guide and iv) a scale is an effective tool to measure variables. These ways of measuring learning are built on an appropriate research design based for instance on the four-level model for evaluation (Kirkpatrick and Kirkpatrick, 2006). The levels are: reaction, learning, behaviour and results. Bearing in mind that one of the objectives of this thesis is to evaluate the effects of games, the decision was made to consider the first two levels. For this reason, and in order to propose a standardised questionnaire to be submitted to players, the MEEGA model (Savi et al., 2011) was chosen to evaluate games and their effects on players. This model was selected among seven different approaches to evaluate educational games: three frameworks (Connolly, 2009; Freitas, 2006; Carvalho, 2012), two scales (Fu, 2009; Ak 2012), one method (Mayer, 2012) and finally one model (Savi et al., 2011).

MEEGA (Model for the Evaluation of Educational Games) was indeed developed for the evaluation of educational serious games. Primarily, it focuses on level 1-reaction - (Kirkpatrick and Kirkpatrick, 2006) by capturing the reaction of players

after they played games. As mentioned above, it proposes a standardised questionnaire through the measurement of three quality dimensions of educational games: motivation, user experience and learning. Added value is derived from the fact that MEEGA is presented accompanied by an implementation process that obviously facilitates its application (Petri and Von Wangenheim, 2016).
MEEGA was used as a reference model to construct the first evaluation questionnaire of the Talenti Polito Challenge. It was adapted to the objectives of the challenge and also used as an evaluation tool to decide the winning games of the competition. Even though it was submitted to a small number of players/assessors - only eight - thanks to its standardisation it was applied to evaluate all 8 serious games developed by the students. In this way it was possible to collect 64 responses to the questionnaires. The results obtained from these responses showed that the games developed respectively: I) met the initial requirements of the challenge, ii) correctly incorporated the SDGs, iii) covered more than two mandatory SDGs, iv) aroused interest and enjoyment in the players, v) did not bore the players, vi) had a good replicability rate and vii) were recommended (positively) as a learning tool on sustainability. Furthermore, at the end of Talenti Polito Challenge the experience of learning from another point of view was also evaluated: that of the developers. This is known in the literature as the opportunity to learn "by making".

c) In the context of Education for Sustainable Development, can a challenge be a compelling and effective novel approach to be adopted for "learning by making"?

In the field of university education, the integration of the European Higher Education Area advocates teaching methodologies that help students develop their skills in an active and meaningful way. Methodologies associated with innovation should be an integral part of daily educational practice and should be sustained by the use of educational and technological resources available (Pozo-Sánchez et al., 2020a). In this context, the use of serious games as learning tools seems to be a promising approach due to their ability to teach and reinforce not only knowledge but also skills such as problem solving, collaboration and communication (Prado et al., 2020; Espinosa and Contreras Eguia, 2016). The use of technological tools and innovative approaches also allows the students to understand abstract concepts (Pozo-Sánchez et al., 2020b). However, technological resources as serious games, created to promote sustainable education (Katsaliaki, and Muysafee, 2015; Rojo and Dudu, 2017) are practically non-existent as teaching tools, which is inconsistent with the development of both pedagogical concepts, information and communication technologies (ICTs), the games themselves and the skills and

characteristics of the students (Calabor, Araceli Moya & Mora, 2018). Moreover, there are hardly any studies that couple these two subjects, serious games and SDGs, in a collaborative learning approach. This thesis aims to contribute to this endeavour. Nonetheless, the results of studies related to the effectiveness of serious games in terms of sustainability are inconclusive and still ongoing. For instance, Ouriachi, Overa-Lobo and Gutiérrez-Pérez (2017) did not find statistically significant results after the use of a serious game. On the other hand, Rojo and Dudu (2017) showed that serious games had an individualistic profile and were limited when working in different areas related to sustainability. However, Katsaliaki and Musafee (2015) stated that these games increased players' understanding of events around sustainability and strengthened their knowledge of sustainable development issues. Furthermore, Prado et al. (2020) found that simulations were more effective than case studies, especially in terms of multidimensionality and intertemporally. In this sense, programming simulation scenarios or developing appropriate serious educational games can contribute to this formative debate.

An opportunity to collaborate and witness first-hand the design and creation of serious games for sustainability issues arose through the Talenti Polito Challenge (Chapter 5). 59 students involved in this internal universities' competition developed specific new serious games for a more sustainable campus. These students faced the challenge of developing, for the first time, a game that was not only fun, but also served an educational purpose in terms of sustainable behaviour. The creation of new serious games for sustainability challenges allowed a close look at a case of learning by making. As explained in Chapter 2, it is possible to learn from serious games not only by playing but also by creating them. For the students, this was a unique learning opportunity and an experience they had never had in a university context. In order to evaluate this type of educational experience, an additional questionnaire was created and submitted to the students involved in the project (Chapter 5). This was designed to assess the challenge as an educational experience and for exploring whether it could be a compelling and effective novel approach to be adopted for learning by making. The majority of the involved students answered the questionnaire (56 replies) and most of them (61%) positively evaluated the learning effects solicited by the challenge (i.e., Learnability sub-scale) alongside 65% of all respondents who reported improved teamwork ability fostered by this experience (i.e., Teamwork sub-scale). However, what caught the eye was the figure concerning the willingness to replicate such a school experience in the future (i.e., Likeability to Repeat sub-scale). Only 37% agreed. This is probably due to the fact that the whole challenge experience took place online and the students never had the opportunity to meet in person and work together. Nevertheless, once the game had been designed and development has begun, most of the difficulties were overcome. As a result, a significantly lower percentage of students (39%)

reported encountering obstacles during this phase. In addition, the positive effects of learning were also observed by the questionnaire items in which students were asked to self-assess their knowledge in the three dimensions of sustainability (i.e., environmental, economic and social). To summarise, the responses to the student questionnaires were positive, which may indicate that there may be a good case for including such educational experiences in the classrooms.

7.2 Key findings and limitations

The most interesting results drawn from the studies carried out in this thesis respectively concern 3 main topics: i) the new classification of sustainable serious games, ii) the Talenti Polito Challenge and iii) the application of the analytical flow chart.

i. The New Classification

Chapter 4 includes the description of the work done to classify 67 serious games tackling sustainability. This new analysis has been carried out starting from a previous classification by Stanitsas et al. (2018), moving on to consulting three online databases concerning sustainable serious games (Games4Sustainability, Games for Change and Serious Games Classification). The classification process was occurred through four main phases: 1) Finding the main serious games; 2) Filtering those main serious games; 3) Tracing the documents through a systematic literature review and finally 4) Synthesising and describing the analytical process (Cravero, 2020). The time period chosen for this analysis takes into account sustainable games developed from 2007 to 2018. With regards to the keywords' selection, expressions similar to 'serious games' were to be employed. This is because, as explained in Chapter 2, this term is often replaced by researchers with other terminologies, such as *digital game-based learning* (Ouariachi et al., 2018), *educational games* (Ouariachi et al., 2018), *environmental games* (Stanitsas et al., 2018) and *game-based learning* (Stanitsas et al., 2018); all of which were included in this analysis. The selection of keywords made to carry out this research was done in the initial stages of this work. Since the use of serious games as educational tools in the field of sustainability and especially of the SDGs is a relatively new field of research, precise decisions were made at an early stage. In fact, it was decided to use keywords that were more generic in order to involve as many studies as possible and that still referred to sustainable development issues. From a certain point of view, this has certainly opened up different research horizons. At the same time, however, this choice did not make it possible to restrict the research to the part related specially to learning assessment. In the initial phase of the research, the choices made were weighted according to the objectives to be achieved. For this

reason and for the next work phases, the research could be expanded to include other keywords such as interactive learning environment, microworlds, serious educational games and business games.
Back to the work on classification, the selected keywords have been applied in combination with the name of each serious game, thus uncovering further information on scientific research database. The research was accomplished by respectively consulting: Google Scholar, Scopus, ResearchGate, SpringerLink, Web of Science, Sage Journal and Google books. As a result, 53 valuable documents were collected.
After executing the analysis through the different stages described above, 705 games were initially identified (149 from *Games4Sustainability*, 234 from *Games for Change* and 245 from *Serious Games Classificatio*n), after which, 126 were skimmed to achieve the final result: a selection of 67 games, considering their market availability.
The analysis of the classified games contemplated seven categories: Year, Genre, Type, Target, Game Theme, Game Topic and SDGs. Particular attention was given to the last category, as this particular classification aims to identify which and how many SDGs are addressed in the games. Such identification was made taking into account the characteristics of each serious game, its game topic, its game themes and the descriptions given in the online referred databases.
The overall outcomes show that SDGs are successfully addressed in the classified serious games. In particular, the majority addressed challenges related to urban issues, sustainable consumption and climate implications. In fact, SDG 11Sustainable Cities and Communities and SDG 12-Responsable Consumption and Production are tackled in 27 serious games, while SDG 15-Life on Land is challenged in 12 games. Therefore, explicit references to the SDGs were found in these serious games. An interesting observation is that it was possible to identify references to the SDGs even in games created before 2015. This may be due to the fact that sustainable games already appropriately addressed the challenges of sustainable development before that date. It would be interesting, for further works, to explore these categories of references in more detail. Perhaps, may there be references to the MDGs or to other goals previously on the UN reports? This research has so far limited itself to identifying references, firstly to sustainable development issues and then to goals. A more detailed analysis of the games could be conducted considering other characteristics (such as length of the matches, number of players, possible internal challenges and bonus, levels' division, threats and contingencies) which were not discussed in this researched.

ii. Talenti Polito Challenge

The experience of Talenti Polito Challenge, offered 59 "Emerging Talents" students of Politecnico di Torino the opportunity to take on the role of developers of serious games. This was a unique occasion, enabling the participants to become active participants in the overarching learning activity. According to the prerogatives of the challenge and the demands expressed by the organisers to the students, the new games required to (i) promote sustainability within the campus of Politecnico di Torino (ii) focus on at least 2 SDGs (iii) involve all the sustainability dimensions (i.e., social, environmental, economic) (iv) provide a minimal gameplay length of 30 minutes and (v) investigate the interconnections/linkages between different SDGs. One of the most valued aims of the challenge, was to encourage students' awareness towards sustainability themes through a constructionist approach. To clarify, *constructionism* entails a learning theory regarding teaching and design, whereby knowledge is better acquired when the learner conceives their own method of learning such knowledge (Xerou et al., 2016). The students' activities were framed according to a social constructionist framework highlighting three crucial activities: the exploration of ideas, the construction of an artifact and the evaluation of such artifact (Parmaxi et al., 2013a, 2013b; Parmaxi and Zaphiris, 2015; Parmaxi, Zaphiris, & Ioannou, 2016). In relation to this thesis, *constructionism* supports the success of learning through the creation of games.

Subsequently, questionnaires and structured interviews were carried out in order to assess the experience of those who actively took part in it. However, the study is limited by the lack of information on learning by playing games. The games developed were evaluated only by 8 people, who were divided into 2 teams of players. The results showed a positive impact in terms of learning, perhaps because the players were experienced teachers or researchers in the field. Nonetheless, the limited number of responses did not allow us to state in absolute terms which games were most efficacious. To evaluate the games more professionally, external sustainability experts were invited, valuing the games' aptness to environmental concerns. Unfortunately, due to COVID-19 and the limited time available, it was extremely difficult to gather the guests and involve them. Further tests and applications would therefore be highly recommended in order to highlight any shortcomings in terms of both game mechanics and sustainability.

Although, fortunately, for what concerns *learning by making*, more detailed assessments were conducted. The collected results showed that students positively assessed the learning effect and their teamwork abilities solicited through the activity "of making". Besides, students' self-assessment in the three macro dimensions of sustainability (i.e., economic, social and environmental) significantly increased from the beginning to end of the challenge. Interestingly, all the positive effects measured in the questionnaire yielded no difference between students who had previous knowledge of playing or making games. Although only 37% of the

participants would be willing to repeat this experience, this value was certainly influenced by the current pandemic. It is crucial to underline that Talenti Polito Challenge were among the very first activities of Politecnico di Torino to be scheduled online just as the first lockdown began in Italy in March 2020. This unfortunate situation made it difficult for students to collaborate distantly for the first time. 32 interviews conducted after the experience supported and consequently confirmed the results of the questionnaires. The questionnaires revealed that, under normal in presence teaching conditions, the students would gladly repeat a similar experience since they had to study, and therefore learn new skills to create the educational games. Further works, as discussed in the last section of this chapter, will involve the collection and analysis of qualitative and quantitative data to evaluate the effectiveness of serious games developed through play sessions with other students (Cravero et al., 2021).

iii. Analytical Flow Chart

The analytical flow chart proposed in this thesis explores how SDGs have been addressed in serious games. From the results of the new classification and the Talenti Polito Challenge, the need to deeply analyse sustainability games was conveyed. Once the SDGs in the games had been recognised and identified, the research could develop through the examination of ways in which notions of sustainability are conveyed.

The results of this investigation are presented in Chapter 6 and show that sustainability knowledge is efficiently conveyed through game mechanics (explained in Chapter 2). The description of the flow chart is partly introduced in Chapter 1, fully explained in Chapter 6 and briefly summarised below. In fact, it is mainly comprised of two elements: one referring to the SDGs and the other to the world of game elements. For the first element, the instrument of the KnowSDG platform of JRC known as *Interlinkages visualisation tool* was chosen as a reference. This tool was used to identify links between the SDGs analysed within the games. In addition, it was used as starting point to identify the links among the goals dealt with in game dynamics. Consequently, the analytical flow chart is based on Werbach and Hunter's (2012) research on game elements and thus on game dynamics and mechanics. In fact, such scientists have identified the 10 most common game mechanics:

- Challenges, puzzles or other tasks that require effort to be resolved;
- Chance, elements of randomness;
- Competition, one player or group wins, and the other loses;
- Cooperation, players must work together to achieve a shared goal;
- Feedback, information regarding the player’s performance;
- Resources Acquisition, obtaining useful or collectible items;

- Rewards, benefits for some action or achievement;
- Transactions, tradings between players, directly or through intermediaries;
- Turns, sequential participation by alternating players;
- Winning states, objectives that make one player or group the winner-draw and loss states related concepts.

Such flow chart has been applied in six games: *Energy City*, *Urban Climate Architect, New Shores: a game for democracy, Patent, Polink* and *iPolito*.
This proposed approach will be proved useful in expanding our understanding of how game elements (taking into account dynamics and mechanics) play a key role in providing sustainable knowledge to the players. By applying the flowchart (see Chapter 6), it was found the most relevant findings relate to how sustainability concepts are transmitted to players. Within the analysed games, sustainability is communicated to the players through innovative projects but also through simple everyday activities. These include, for instance, awareness campaigns (such as vegan week or zero-km food), low or zero-emission transport systems (including cycling, car sharing, electric cars), an increased number of green areas and the installation of photovoltaic panels. Furthermore, simple daily actions such as turning off the tap, switching off classroom lights or PCs, bringing a packed lunch from home and using a reusable water bottle contribute to improving people's behaviour. All these actions were implemented in the games through the design of the game mechanics. Moreover, the majority of the game mechanics designed in the selected serious games can be summarized in 2 macro groups: indicators and projects/actions/initiatives to be carried out within the serious game. The indicators analysed in these six games tend to be represented as mechanic "feedback" (information on the player's performance while playing) and as "winning states" (goals that make a player or group successful). On the other hand, projects/actions/initiatives tend to be proposed in games through the mechanics of "resource acquisition" (obtaining useful or collectible items), "rewards" (benefits for some action or achievement), or "feedback" (information on the player's performance while playing). As can be seen, this research limited itself to cataloguing game mechanics according to the studies of Werbach and Hunter (2012). However, this may be limiting, as there is a tendency to identify game mechanics in at least one of these categories. If other studies on game mechanics were taken into account, this problem may be counteracted.
In conclusion, the last considerations concern SDGs. Since the analysis of game mechanics has involved projects of an economic, environmental and partly also social nature, the greatest references to SDGs have been seen in projects comprising of energy incentives, sustainable transport, increases in green areas, sustainable

initiatives and more conscious behaviour. According to all these projects, as emerged from the six serious games examined, the most investigated SDGs have been SDG 11- Sustainable cities and communities, SDG 12- Responsible consumption and production, SDG 13- Climate action whereas in just 4 games, SDG 7- Affordable and clean energy and SDG 6- Clean water and sanitation.

7.3 Future development

The research carried out in this thesis can certainly open up future scenarios for further work. Such scenarios could mainly concern two future applications: firstly, by promoting the challenge games as a training tool (both and making and play) and secondly, by further testing the flowchart on other serious games. Some considerations can be made according to the possible applied scenarios of the challenge's games that are linked to the learning methods. Also, the opportunity to learn by making was positively evaluated by the students involved in this experience. Regarding the use of the challenge games as an educational tool, new works are already underway to test them with other students. In fact, they were recently used as an educational and aggregative activity for the First Unite Spring School on Energy, also held online from 17th-19th May 2021. I was personally in charge of organizing and coordinating team-building activities that were also educational for the students attending the school. It was consequently established to apply two games from the challenge, Patent and Polinks, to bring the students closer to the theme of sustainability and also to give them the opportunity to get to know each other and "team up", albeit from a distance. 30 students involved were also given pre- and post-questionnaires to assess the success of the games as educational tools on sustainability. Initial results show a positive evaluation of the game experiences and a positive growth in the economic, social and environmental aspects of sustainable development. Activities of this kind show how serious games can be easily pursued in future applications also different from universities' contexts.

Within this thesis the experience of learning through games has only been dealt within a university educational context. The urban dimension was therefore chosen as the campus dimension. Having involved the students, it was decided to make them think about a dimension and a reality that they knew very well. Living the Politecnico every day, they are perfectly aware of the criticality of the area in which it is located, the access routes and the services it offers. Knowing the campus well, it was therefore easier for the students to imagine the game scenarios, the characters, the unexpected and the opportunities available. This first experience was a test; future research should certainly be extended. An interesting work would be to extend the experience of learning by making to other universities, to see how other students relate to the urban dimension of their campus.

Furthermore, these experiences can be extended to a different audience and to other areas of the cities. Urban living labs could host these initiatives. Urban living lab is a growing trend to involve citizens in city development, in order to make urban areas more adapted to citizens' needs. When addressing sustainability issues such as the consequences of climate change and urbanisation in cities (air pollution, flooding, and heat stress) it is important to think ahead, and at the same time, to consider the social implications of the solutions that are introduced in urban areas. Complex issues should be addressed by involving a range of stakeholders, including citizens, companies, research, academia and the public sector, to ensure the successful collaboration towards the shared solutions (https://unalab.eu/en/urban-living-labs).

Urban Living Labs are the orchestrators of this collaboration, bringing together the different stakeholders through co-creation activities and collaborations. Co-creation involves different phases of development to reach the final solution. For instance, creations of serious games could be an interesting activity to discuss and implement in urban living labs. The involvement of citizens and other stakeholders could give a wide range of opportunity to tackle urban issues from different points of view.

According to the further development of the flow chart applications, some considerations may be useful. An interesting scenario would be to investigate other possible uses of this flowchart based upon these preliminary considerations. For instance, can the analytical flow chart be used in a reverse way to build new games and define new synergies? The outcomes show that this flow chart could be a valid starting point for analysing both existing serious games and new sustainable serious games. The possible further developments, may include the use of this flow chart to design and realize appropriate games for increasing knowledge of sustainability challenges.

To close this digression, it is important to bear in mind that, more applications and tests could be useful in the exploration of sustainability challenges, to contribute in the scientific debate. Firstly, it would be interesting to continue to apply this flow chart to other games in order to enrichen it. Further applications would allow the research to pursue, collecting more data to analyse. Secondly, involving sustainability experts in future research could be stimulating, through their consultation they could provide useful advice and more in-depth knowledge on the subject with a critical eye.

Glossary

Citizen design science: is a science that studies the role and centrality of people, citizens in particular. This science is the focus of co-creative projects where researchers and citizens work together on a project, in most cases. In these situations, the users involved can express their ideas through a systemic form of design.

Education for sustainable development: derives from Environmental Education (EE) and is defined a student-centred educational area that aims to motivate pupils and young people to become actively involved in the learning process for environmental and societal issues.

Gamification: is a term originally conceived by the digital media industry. The most known definition declared that it is "the use of game elements and game design techniques in non-game contexts" (Deterding, et al., 2011).

SDG 11: is the goal focusing on smart cities and communities. This goal is useful for "Making cities more inclusive, safe, resilient and sustainable". SDG 11 is divided into 7 targets structured in 15 different indicators. "Many cities around the world are facing acute challenges in managing rapid urbanization, from ensuring adequate housing and infrastructure to support growing populations, to confronting the environmental impact of urban sprawl, to reducing vulnerability to disasters" (sustainabledevelopment.un.org/sdg11).

Serious games: are generally defined as learning tools. Clark C. Abt (1987), defined such games as a "particular way of looking at something, anything… 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 not be, entertaining". Moreover, serious games are also defined as educational games and instruments that allow users (the players involved) to learn and practice issues in a gamified approach.

Smart cities: are cities that offer citizens a certain level of services and which, through the use of ICT technologies, enable them to produce data and information useful for sustainable development to improve the quality of life.

Sustainable campus: is a sustainability-conscious campus designed with sustainable development in mind. Universities are a good test bench to involve specific target

users (students, professors, academic staff) towards sustainable urban issues. "Universities can optimize their role as agents of change about sustainability by adopting a 'whole-of-university' approach to sustainability. This approach explicitly links research, educational, operational and outreach activities and engages students in each" (Mcmillin, J., Dyball, R., 2009).

Sustainable communities: comprise of a group of people, often citizens or specific target users, oriented to sustainability transition. This theme is partially involved in SDG 11, within target 11.3- "By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries" (sustainabledevelopment.un.org/sdg11).

Sustainable development: was first formalised in the Brundtland Report in 1987. It was defined as "the development that meets needs of the current generation without compromising the ability of future generations to meet their own needs" (Brundtland, 1987. p. 43).

Sustainable Development Goals (SDG): are a call for action demanded by all countries (poor, rich and middle-income) to promote prosperity while protecting the planet with sustainable actions and decisions. They are a list of 17 sustainable goals developed and analysed through 167 different targets. "They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities while tackling climate change and environmental protection" (www.un.org/sustainabledevelopment/).

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Appendix A

Table 25_ Model for the assessment of sustainable interlinkages identified in Patent by Group 1

SDGs and Targets	Short description	YES/ NO	POLINKS		
Dimensions			**Social-Human wellbeing**	**Environment**	**Economic**
SDG-4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	NO			
How?					
SDG-6	Ensure availability and sustainable management of water and sanitation for all	YES	X	X	
How?	Synergies: additional points with other patents		-Water bottle and water supply points	-Water purification systems - Rainwater tanks - Sinks with photocells	
SDG-7	Ensure access to affordable, reliable, sustainable and modern energy for all	YES		X	X
How?	Synergies: smart grid with many other cards. Trade off: thermal power plant			- Photovoltaic windows -Bike energy storage -System to retrieve energy from wastewater - Classroom thermoregulation -Benches with recycling bins	
SDG-9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	YES		X	
How?	Less-discussed goal			-Thermal insulation -Temperature control -Green walls	
SDG-11	Make cities and human settlements inclusive, safe, resilient and sustainable	YES	X	X	X
How?	Synergies: with energy systems		-Car pooling for students and professors - Anti-littering campaign - Courses on mass public transport design	-Ride sharing parking slots -Charging stations for hybris and electric vehicles -Electric cars - Separate waste collection	-Discounted bus season passes

SDG-12	Ensure sustainable consumption and production patterns	YES	X		
How?	Trade-off: plastic caterpillar		-0km food for canteen -Vegan week - Recycling research workshops -Rooftop vineyards		-Plastic caterpillar
SDG-13	Take urgent action to combat climate change and its impacts	YES	X	X	
How?			-Vegetable garden -Planting trees for every flight made (professors and students) -Smart autonomous irrigation systems -Online courses, conferences and meetings	-Biodynamic cement (purifies air from co2) -Bio-reactive façade -plant	
SDG-17	**Strengthen the means of implementation and revitalize the global partnership for sustainable development**	**YES/NO**			
How?	Rethinking and downsizing SDGs for the campus				

Table 26_Model for the assessment of sustainable interlinkages identified in Polinks by Group 7

SDGs and Targets	Short description	YES/ NO	POLINKS		
Dimensions			**Social-Human wellbeing**	**Environment**	**Economic**
SDG-4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	NO			
How?					
SDG-6	Ensure availability and sustainable management of water and sanitation for all	YES	X	X	
How?	Synergies: additional points with other patents		-Water bottle and water supply points	-Water purification systems - Rainwater tanks - Washbasins with photocells	
SDG-7	Ensure access to affordable, reliable, sustainable and modern energy for all	YES		X	X
How?	Synergies: smart grid with many other cards. Trade off: thermal power plant			- Photovoltaic windows -Bike energy storage -System to retrieve energy from wastewater - Classroom thermoregulation -Benches with recycling bins	
SDG-9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	YES		X	
How?	Less-discussed goal			-Thermal insulation -Temperature control -Green walls	
SDG-11	Make cities and human settlements inclusive, safe, resilient and sustainable	YES	X	X	X
How?	Synergies: with energy systems		-Ride sharing parking slots -Car pooling for students and staff - Anti-littering campaign -Courses on mass public transport design	-Charging stations for hybris and electric vehicles -Electric cars - Separate waste collection -Experimental backyard vegetable garden	- Reimbursement of public transport subscriptions

SDG-12	Ensure sustainable consumption and production patterns	YES	X		
How?	Trade-off: plastic caterpillar		-0km food for canteen -Vegan week - Recycling research workshops -Rooftop vineyards		-Plastic caterpillar
SDG-13	Take urgent action to combat climate change and its impacts	YES	X	X	
How?			-Vegetable garden -Planting trees for every flight made (staff and students) -Smart autonomous irrigation systems -Online courses, conferences and meetings	-Biodynamic cement (purifies air from co2) -Bio-reactive façade -plant	
SDG-17	**Strengthen the means of implementation and revitalize the global partnership for sustainable development**	**YES/NO**			
How?	Rethinking and downsizing SDGs for the campus				

Table 27_Model for the assessment of sustainable interlinkages identified in iPolito by Group 4

SDGs and Targets	Short description	YES/ NO	iPOLITO		
Dimensions			**Social-Human wellbeing**	**Environment**	**Economic**
SDG-4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	YES	X		X
How?	Desk of "decision" cards, some synergies with SDG 10		-Sustainable weekends to raise awareness -Project with Talents -Online courses - Arabic writing course		-Division by income bracket
SDG-6	Ensure availability and sustainable management of water and sanitation for all	YES	X	X	X
How?	Synergies with SDG 12 and SDG 15		-Water fountains inside the campus -Polito bottle	-Replacement of services with dual flash - Water purification of the Po river - Rainwater collection system	- Replacing new sanitary fixtures with photocell
SDG-7	Ensure access to affordable, reliable, sustainable and modern energy for all	YES		X	
How?				-Crystalline silicon photovoltaic panel - Light ignition sensors -Thermal insulation with an overcoat -Initiative "I light up less" -Low enthalpy geothermal plant -Centralized air conditioning	
SDG-9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	YES	X	X	X
How?	Deck of "collaboration cards" to establish private or public partnerships, deck of "decision cards" with actions and activities		-Business incubator (Living Lab)	-Extension of new buildings or re-use of existing buildings -District heating system -Bacteria that degrade plastic	-Business incubator (Living Lab)

	giving synergies with SDG11, SDG 12 and SDG 13				
SDG-11	Make cities and human settlements inclusive, safe, resilient and sustainable	YES	X	X	X
How?	Synergies: among some cards from the decisions deck and collaboration deck (SDG12, SDG13)		- Sustainable weekends to raise awareness -Museum season tickets -Lunchbox	-Carpooling -Car sharing -Green roof (“Orti Alti” project) -Bio bottle	-Bike rental services
SDG-12	Ensure sustainable consumption and production patterns	YES	X	X	X
How?	Synergies: Rainwater collection system (SDG6), BiosPHera 2.0 (SDG 8, SDG 9, SDG 11), CCU- Carbon Capture Utilization (SDG9, SDG11, SDG 13)		- Conferences on the impact of food on the environment -Internal mini-game on separate collection	- Solid ink printers -Biodegradable bottles -Collection of paper	-BiosPHera 2.0 -CCU (carbon capture Utilization)
SDG-13	Take urgent action to combat climate change and its impacts	YES	X	X	X
How?	Synergies: New Living Lab (with SDG8 and SDG12); Carpooling (SDG11); Bike rental (SDG11-upgrading card with bike parking)		- Courses on sustainability -Talent projects initiatives -Measures to encourage the use of bicycles by students	-Electric car charging stations -Research on bacteria that capture CO2	- Bike rental services -Bike parking
SDG-17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	YES/NO			
How?	Less discussed than others The strengthen are defined among the cards and also between two pairs of players. This goal represents relations among players and game mechanics				

Table 28_Model for the assessment of sustainable interlinkages identified in 4...3...2...1...Sustainability by Group 6

SDGs and Targets	Short description	YES/ NO	4…3…2…1…Sustainability		
Dimensions			**Social-Human wellbeing**	**Environment**	**Economic**
SDG-4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	NO			
How?					
SDG-6	Ensure availability and sustainable management of water and sanitation for all	YES/NO	X	X	
How?	Less discussed than others		-Drinking water bottles and fountains	-Water system monitoring (groundwater conditioning system)	
SDG-7	Ensure access to affordable, reliable, sustainable and modern energy for all	YES	X	X	X
How?	Main mechanic: pawns moving on the game table		-Insulating windows and windows -Efficient ventilation systems	-Led lights -Micro-wind power plants -Photo insulating panels - Solar thermal system	-Poles charging electricity in green areas
SDG-9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	NO			
How?					
SDG-11	Make cities and human settlements inclusive, safe, resilient and sustainable	YES	X	X	(x) symbolic value
How?	The floor plan of the campus is the board of the game: sustainable projects are carried out on campus		-Rack for bicycling parking -Bike-sharing membership	-Bike path implementation with the bike paths of the city -Waste bins for separate collection -Electric car poles	
SDG-12	Ensure sustainable consumption and production patterns	NO			
How?					
SDG-13	Take urgent action to combat climate change and its impacts	YES	X	X	

How?	Synergies: actions also traceable to SDG7		-Degree course in climate change -Initiatives as “I light up less”	-Reduction of CO2 emissions -Composting -LED lighting - Insulation of radiant panels - Glass solar panels - Green roof -District heating system	
SDG-17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	YES	X	X	(x)1
How?	Important game mechanics: system improvements that work in pairs between 2 players that collaborate to realize the plant [1]real and concrete references in the game			-Energy plant realization	