Contents

Emerging Technologies and Frameworks for Serious Games

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Abstract

More than fifty years have passed since serious games first appeared, and the goal of serious games is to motivate players to learn and improve their learning outcomes. Players are given specific tasks and challenges combined with entertainment and engagement. Serious games have evolved from the traditional video game-like modality of play to diverse, playful, real-time interactive systems, also harnessing, for instance novel extended reality interfaces. A serious challenge that arises is the rewarding process, which varies depending on the problem that they are attempting to solve and the technology involved. The complexity of the game also plays a significant role. The purpose of this chapter is to address these issues and provide an insight not only into the technological challenges, but also into foundational theoretical frameworks

1 Introduction

Serious games aim to improve learning outcomes by leveraging games' motivational and engaging nature. While serious games might be considered relatively new compared to other established fields of research [1], learning and playing as well as combining the two have been investigated for a very long time. Ancient Greek philosophers have already approached this question of learning through play [2]. The globally played game of chess was originally played to master different strategies of war [3]. Similarly, the traditional African game known as Oware has been played for thousands of years, and is still used today to learn the multiplication tables [4, 5]. The use of games for learning has been discussed extensively throughout history, but within the past few decades, game-based learning has become a whole field of research, and numerous definitions of serious games have been attempted, including minute elaborations of their constituents. Some emphasize their video game-like nature [6], while others relate to other forms of play such as board games or even outdoor games [7]. In [8], Alvarez et al. introduced the notion of the serious games definition based on their two inherent dimensions, i.e. seriousness and play. Their definition unified preceding ones and broadened the range of included serious games. Section 2 will establish the relationships of this particular defintion and other ones more thoroughly, and shed light on their concrete constituents and the resulting classifiaction schemes of serious games. This brief overview will conclude with the insight that no matter which definition of serious games or which classifcation a concrete instance, all of them aim to convey knowledge—whether to honestly enrich the players' horizons or to manipulate their opinions, for better or worse. Therefore, the subsequent Section 3 sheds light on educational serious games more specifically, giving several examples. In their context, the means of knowledge communication, teaching and learning have been explicitely and systematically applied. To ensure that both dimensions of play and education are well-addressed, rigorous assessments of serious educational games have been pursued, which are also outlined in Section 3. Naturally, Section 4 will provide an overview of pedagogical theories and frameworks that have frequently been built on in the context of serious (educational) games. These elaborations will be complemented by approaches to game design in general and serious game design in particular, outlined in Section 5.

2 Serious Games Definitions & Taxonomies

A game can be defined as a system in which players engage in artificial conflict with rules that lead to quantifiable outcomes [9]. Whichever definition of a game we follow, it is the artefact emerging from a design process and it is comprised of several elements [10]: There are "entities" that engage in interactions, sometimes referred to as agents, i.e. whose referential focus lies on the fact that they follow their own agenda or act on their own. Some entities might also be referred to as operators emphasising their role in the operation, i.e. in driving the game from one state to the next. A game's "mechanics" are generally understood as the methods invoked by agents that make the transitions between game states actually happen. There needs to be "space" to represent a game's state and to allow to engage and there needs to be some understanding of "time" to ensure that engagement can happen and transitions can follow. The specification of "goals" of a game are yet another aspect that the aforementioned definition (and many others) imply.

Learning, on the other hand, is the process of acquiring knowledge. Game-based learning [11], for instance, refers to using games in a learning context, i.e. where an established learning environment or concrete situation is enriched by means of playful interaction with the learning material. Gamification also enriches a non-gaming context. But instead of providing a game for a given context, game elements and mechanics are introduced directly into a given context [12]. This means that although the contents do not change, the learners' or players' overall experience is improved by means of various measures such as enhancing feedback, definition of tasks and goals, introduction of playful competition, etc. Using the term serious games [13], one usually does not focus on the enrichment or augmentation of a given context but rather on the pursuit of a given serious (learning) objective and its realisation by means of an aptly designed game [14, 15].

The term was first coined by Abt in [7, 9]. A serious game is defined as a game that is not simply intended for entertainment purposes but which relies on entertainment to promote training, education, health, public policy, and strategic communication [16]. According to Sawyer, a serious game is a way for developers, researchers and industrialists to use video games and video game technologies outside of entertainment [6] . The concept of a serious game, as defined by Djaouti et al./ is one that combines both serious aspects in a computer application, such as non-exhaustive where the emphasis is on the most important or fundamental concepts of a subject, non-exclusive teaching where a variety of approaches are employed in order to cover the subject matter, learning, communication, and information infused with playful elements drawn from video games [1]. Accordingly, a serious game is one that was designed for purposes other than simple entertainment.

2.1 Serious Games Taxonomies

A serious game taxonomy is a classification system for different types of serious games. There are many different ways to classify serious games, and different taxonomies may focus on different aspects of the games. For example, some taxonomies may classify serious games based on the intended audience, e.g. children, adults, or seniors, while others may classify them based on the specific skills or knowledge they are intended to teach. The importance of taxonomies for serious games cannot be overstated. In order to understand the variety of options available and how they differ from one another, it is essential to classify and organize different kinds of serious games.

2.1.1 General Purpose Categorization

In their article, Djaouti et al. (2011) discuss the importance of classifying both serious and game dimensions. A major objective of their classification is to help people navigate the wide field of serious games (e.g., teachers looking for a suitable educational game). This dual nature of their proposal, as well as the model G/P/S, is reflected in their work. Uskov and Sekar (2014) add certain criteria and subcriteria to Djaouti et al.'s proposal (2011) while maintaining the original criteria. As part of their work, they emphasize the importance of creating a serious game classification to gain a deeper understanding of serious games' purpose, scope, domain, type, gameplay, and audience.

2.1.2 Application Domain-based Categorization

Zyda (2005) classified serious games according to several application domains [16]: Healthcare, Public policy, Strategic Communication, Defense, Training & Education. As described by Alvarez et al. (2007), serious games can be classified into four categories based on their application domains or areas: edutainment, advertising, edumarket games, political games, and training and simulation games [17]. Such classifications, however, focus on certain very specific aspects while disregarding all others.

3 Serious Educational Games

A serious game's purpose could, for instance, target procedural training or experimentation with simulation models. Serious games can be used in a wide range of application contexts, including commercial advertisement [18], spreading news [19], or pursuing recruitment [20]. A serious educational game, on the other hand, is specifically designed for educational or training purposes [21]. These games are often used in a classroom or other learning environment to help students learn or develop certain skills. They can be used to teach a wide range of subjects, including math, science, history, language arts, and social studies [22]. In summary, serious games can be used for a variety of purposes, while serious educational games are specifically designed for education and training.

3.1 Requirements

In order for a serious game to serve as an educational tool, it must address a number of questions related to pedagogy and learning [23]: (1) What are the learning objectives? (2) How can instruction be designed to achieve those learning objectives? (3) What methods are used to assess the achievement of the learning objectives? (4) Are the learning objectives, instructions, and assessments in accordance with one another? As another aspect of serious educational games, there is the game dimension and everything that goes with it in terms of game elements and game design. Serious Educational Games [24]

Due to the variety of variables involved in different learning contexts, defining efficacy in educational contexts can be challenging [25].

A key objective of applying games to higher education is to engage students in complex problem spaces that mimic real-life situations without imposing unwanted constraints and risks. It is the learners' responsibility to develop knowledge representations and reasoning strategies that are relevant to the topic at hand [26].

3.2 Examples and Analysis

One example of a serious educational game that has been widely discussed in academia is "SimCityEDU: Pollution Challenge!". It is a city-building simulation game that is designed to teach middle school students about environmental science and civic engagement. In the game, players must build and manage a city while also addressing environmental challenges such as pollution and climate change. The game is designed to be played as part of a classroom curriculum, and includes features such as adaptive difficulty, performance tracking, and teacher resources [27].

Civilization IV: Democracy & Diplomacy": This game is a turn-based strategy game that is designed to teach high school students about world history, civics, and geography. The game is set in the ancient world and allows players to build and manage civilizations, interact with other civilizations, and make decisions about trade, diplomacy, and war [28].

3.3 Differences with Video Games

The design of serious games still remains difficult to achieve [29]. In theory, the software technologies used for serious games are identical to the technologies used in video games [30]. However, this is typically not the case for several reasons. The most important one is the budget restrictions of developing video games. The level of computer graphics, computer animation, artificial intelligence, human computer interaction, networking and other issues involved in the production of a video game requires a huge budget and in many cases video games are more expensive than producing a movie. So, serious games are constrained to the use of 'easier' and 'cheaper' solutions such as 2D/3D game engines (such as Unity and Unreal), animation (i.e., flash) and authoring tools (i.e., Adobe). Another reason is that serious games often rely heavily on pedagogy and not on entertainment. In many cases, pedagogy is the driving force behind the game and in such applications the implementation is not polished and optimised. However, a theoretical/conceptual framework is typically used allowing for measurable results. It is worth mentioning here that this view is not shared by all scholars, for example Zyda [31] argues that while pedagogy is an implicit component of a serious game, it should be secondary to entertainment. This implies that a serious game that is not 'fun' to play would be useless, independent of its pedagogical content or value. Another difference relies on the interaction techniques [32] as well as in the tracking used in serious games (health and military application domains are the most important ones). Traditional video games are mainly focused on either keyboard/mouse, dedicated controllers, and touch-screen interaction. Serious games are often more experimental and because they have a much smaller market, they are open to experimentation and custom-made interaction techniques and approaches. Body tracking technologies are also used frequently in serious games by combining position and orientation sensors.

Games engines nowadays also provide support for both virtual and augmented reality applications in desktop and mobile environments. This is of great importance since it is practically very convenient for developers with limited experience in virtual and augmented reality to deploy applications through the game engine either on headsets (i.e., Oculus Quest 2), on mobile devices (i.e., smartphones and tablets) and desktop environments. There are also numerous tutorials over the web which allow even beginners and inexperienced programmers to quickly create scenarios that can be used in serious games. As a result, serious games are widely using virtual and augmented reality technologies [30], [33], [34] much more compared to video games.

Depending on the target audience, the technologies vary a lot, and this is a significant difference compared to traditional video games. For instance, for elderly players, the technology is mainly focused on 2D information. The types of serious games applications are mainly focused on problem solving and pedagogical and learning aspects are clearly demonstrated. On the other hand, for younger players exactly the opposite happens. The main drive is entertainment and pedagogical/learning aspects are usually 'hidden'. Here we observe that most of the serious games are either photorealistic 3D games or virtual and augmented reality applications.

Providing feedback in serious games is another great difference with video games. This happens because there are different types of learning approaches and frameworks. In video games development the majority of the game studios follow a similar approach about providing feedback to players. On serious games, there have been examples of having multiple types of feedback and sometimes personalized or unstructured. Unstructured feedback can be provided through collaborative serious games where the subject expert and the learner(s) are collocated in the environment. This is a huge difference compared to video games, where the aim is to foster player satisfaction.

In the future things might change completely and we might see a convergence of serious games with video games. For this to happen, the serious market must grow significantly and match (or get close in terms of revenues) to the market of video games. Content development costs must drop significantly so that they can be used as assets in serious games. We are observing more and more content produced procedural but the cost of other techniques (i.e., lidar, photogrammetry, etc) should drop. Finally, artificial intelligence will play a very significant role, allowing for pedagogical driven games to be used in all types of application domains.

4 Pedagogical Theories & Frameworks

The previously discussed taxonomies of serious games underline their multifacetted nature, also with respect to the learning goals, the targeted students, the envisioned context, etc. In the previous section, several according examples were presented and their diversity emphasised. Pedagogical theories and frameworks help to systematically cope with the large design space of serious games, as they inform us about how their goals can be addressed. Therefore, in this section, we provide an overview of theories and frameworks that underpin the interplay of learning and gaming.

4.1 Theories of Learning

The learning process has been formally described by several theories over the past century . Learning theories have their roots in philosophy and epistemology, such as Plato's works, John Locke, and David Hume . Modern science has incorporated these theories into educational psychology as a framework to explain how individuals acquire, retain, and recall knowledge . The three major theories of learning include behaviorism, cognitivism, and constructivism [35].

Behaviorism aims at understanding and explaining the behavior of humans and animals [36]. It stipulates that every theory in psychology must be supported by empirical evidence gathered through careful observation and measurement. It assumes that people have no free will, that their behaviors are "blank slates" at birth and are shaped by responses from the environment. Hence, an ideal learning process requires performing an appropriate stimulus that triggers a favorable response. Behaviorists also emphasize the importance of repetition: It is necessary that students are regularly reminded of their expected behavior.

Cognitivism, i.e. the cognitive theory of learning, examines how the mind receives, organizes, stores, and retrieves information [37]. The cognitivist movement emerged as a reaction to behaviorism arguing that behaviorists neglect to explain cognition and mental processes. It emphasizes how the learner internalizes knowledge and how learning takes place in the mind. In terms of teaching, it focuses on optimizing learning environments that minimize cognitive workloads. In other words, it mainly contributes to the realization of learning objectives by suggesting how knowledge and information should be presented to the learner, specifically considering the mechanics and limitations of working memory and cognitive workload.

Constructivisim postulates that knowledge is constructed on existing knowledge [38]. It claims that learners do not acquire knowledge and understanding as passive receptors of a direct transmission, the basis of traditional lecturing [39]. Instead, knowledge and understanding are acquired through experience and social discourse by integrating new information with one's prior knowledge.

4.2 Instructional Design & Bloom's Taxonomy

Instructional design frameworks are systematic approaches to the design and development of educational materials and experiences [40]. These frameworks provide a structured process for defining learning objectives, creating instructional materials and activities, and evaluating the effectiveness of the instruction. A few common instructional design frameworks include: (1) the ADDIE model/cite[molenda2003search] which considers the five stages of analysis, design, development, implementation, and evaluation, (2) the SAM model [41] emphasizes the role of learner engagement and motivation in the design process and includes the stages of engagement, activation, and modification, (3) the ARCS model [42] focuses on the learners' attention, their perceived relevance, their confidence, and satisfaction, (4) the 5E model [43] is often used in science education, and includes the stages of engagement, exploration, explanation, elaboration, and evaluation.

Instructional design answers questions on how to convey specific knowledge to learners, how to change people's attitudes, and how to enable them to acquire new skill sets. The according basic questions quickly lead to more fundamental questions, e.g. on the nature of knowledge and on effective processes to convey it. Therefore, instructional design frameworks need build on top of learning theories and guide the designer through assessing concrete learning needs, to rely on apt learning procedures, to develop supporting materials and provide means to evaluate the achieved effectiveness. Throughout the last century, various learning theories have been used to develop systematic frameworks for instructional design

4.2.1 The Revised Bloom's Taxonomy

Based on the revised version [44], the taxonomy has been divided into two dimensions: Knowledge types and Cognitive processes. Knowledge types represent the different types of knowledge to be conveyed to the learner, and cognitive processes represent the level of thinking where this knowledge is processed by the brain. As an example, factual knowledge represents knowledge of specifics, such as dates, names, and events. It is possible to use this knowledge type in conjunction with a specific cognitive process, e.g. remembering, to formulate a learning objective such as "the student should be able to recall the names and symbols of all atoms in the periodic table". Conceptual knowledge refers to the ability to classify and categorize objects and phenomena. If the cognitive process of understanding is combined with conceptual knowledge to formulate a learning objective, it would, for example, yield "the student should be able to sort the atoms by group in the periodic table".

Cognitive processes, the second introduced dimension, represent the mental processes that we use to process information and help us understand the world around us. These processes include perception, attention, memory, language, problem solving, decision making, learning, thinking, judgement, and creativity.

5 Game Design Frameworks

The popularity of video games has grown tremendously in the second half of the last century [45], and since then, the development of video games has progressed at an astounding rate, so that seventy years later, we can enjoy games such as Assassin's Creed, Cyberpunk, Half-Life, etc. Designing a game can be a complex undertaking [46], since there are many factors to consider. In addition to defining the game's mechanics and gameplay, game designers are responsible for developing a compelling and clear concept for the game, structuring the game's progression and difficulty, creating engaging and interactive levels or environments, creating a coherent and immersive narrative, and balancing game elements such as power-ups, weapons, and enemies within the game. In spite of the fact that game design can be a complex and multifaceted process that requires a variety of skills and knowledge, game design frameworks can be helpful in facilitating the design process by providing a structured approach to the planning and implementation of its various components. They provide a way for designers to think about and organize the various components of a game, and to consider how they fit together.

Game design frameworks are used to assist game designers in planning, structuring, and implementing a game. By providing a systematic approach to the design process, they allow designers to take into account all the necessary aspects of a game and how they interrelate. Several types of game design frameworks exist, each with its own specific focus and approach. There are frameworks that, by their very nature, provide a broad overview of the design process and provide designers with guidance through the various stages of the design process. Others focus on a specific aspect of game design, such as mechanics, level design, or story development.

Game design frameworks can be used to define the core mechanics of a game, develop a compelling game concept or theme, structure the progression and difficulty of a game, create engaging and interactive levels or environments, develop an engaging narrative or narrative, balance game elements, such as power-ups, weapons, and enemies, and test and iterate game design concepts.

5.0.1 The Bartle Taxonomy

The Bartle taxonomy of players is a classification of video game players based on their preferred actions within the game [47]. This taxonomy was developed using a character theory consisting of four characters: Achievers, Explorers, Socializers, and Killers. As shown in the diagram 1, the X axis represents the preference for interacting with other players as opposed to exploring the world, and the Y axis represents the preference for interaction as opposed to unilateral action.

Typically, game designers use the Bartle Taxonomy to understand the motivations of their players and to design games that appeal to different types of players [48]. By understanding the primary motivations of their players, game designers can create gameplay elements and reward systems that are tailored to the needs of different player types.

It is common for a game designed to appeal to "killers" to include competitive multiplayer modes, leaderboards, and other features to encourage players to compete against each other. It is likely that a game designed to appeal to "achievers" will include challenging tasks and achievements for players to achieve in order to earn rewards.

In addition to being used in the context of gaming, the Bartle Taxonomy is sometimes used to understand people's motivations in other contexts such as educational games [49]. Using the taxonomy, one can understand what types of activities different types of users are most interested in, and tailor online experiences accordingly.

5.0.2 The Four Keys to Fun

The 4 Keys to Fun is another design framework created by game designer and President of XEODesign Nicole Lazzaro. Lazzaro spent many years researching and designing engaging games. Based on her experience, she has derived four types of fun that engage people within games. Types of fun: (1) Hard Fun

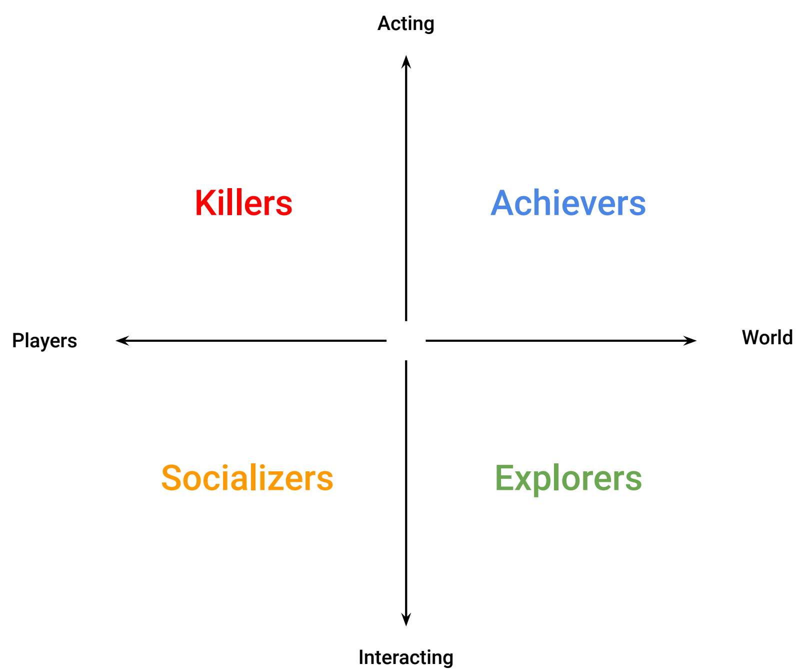

Figure 1: Bartle's Taxonomy Diagram

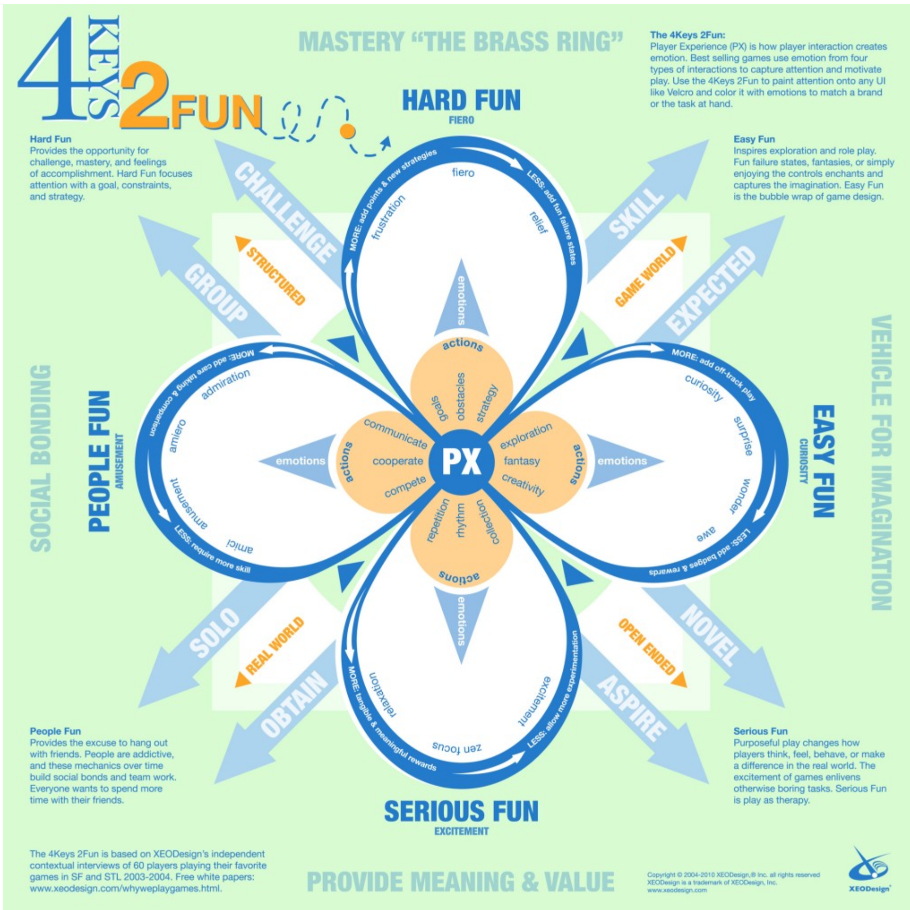

Figure 2: The Four keys to fun

is about Mastery, "The Brass Ring", and when one succeeds in this area, one feels fiero. (2) Easy Fun is a vehicle for imagination. (3) Serious Fun provides meaning and value and we feel excitement upon success. (4) People Fun is experienced with others, where we experience amusement upon accomplishment [50].

5.0.3 The MDA Framework: Mechanics, Dynamics, Aesthetics

A framework developed by Hunicke and Hunicke in 2004 called the MDA framework [51] breaks down how a game can be consumed into its distinct components: Rules, System and Fun, thereby making it a more modular process. In addition, it outlines their design counterparts: Mechanics, Dynamics, and Aesthetics. At the level of data representation and algorithms, mechanics describes

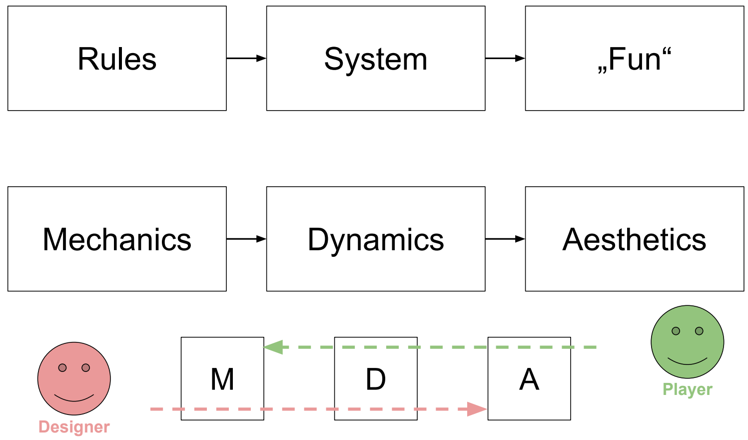

Figure 3: MDA Framework

the specific components of a game. As the player's inputs and outputs change over time, dynamics describes the run-time behavior of the mechanics. During gameplay, aesthetics refers to the emotions invoked in a player by the game system.

5.0.4 The Layered Tetrad

The Layered Tetrad is composed of four elements—as was Schell's elemental tetrad—but those four elements are experienced through three layers. The first two, inscribed and dynamic, are based on the division between Fullerton's formal and dynamic elements. In addition, a third cultural layer is added that covers the game's life and effects outside of play, providing a link between game and culture that is critical to understand for us to be responsible game designers and creators of meaningful art.

5.1 Serious Game Design Frameworks

The process of creating and integrating serious games is time-consuming and financially costly. Traditionally, standards have been used as a means of simplifying the process. In addition to pedagogical and instructional design, these standards also address game design and gamification but one of the major challenges of serious game design is to integrate those standards in a seamless manner. Various methodologies have been proposed, from model-driven architectures to frameworks based on metamodels and ontologies. Throughout this section, we will explore the differences and similarities between these different frameworks [52]. Before doing so, let us outiline the difference between models, metamodels and ontologies [53]

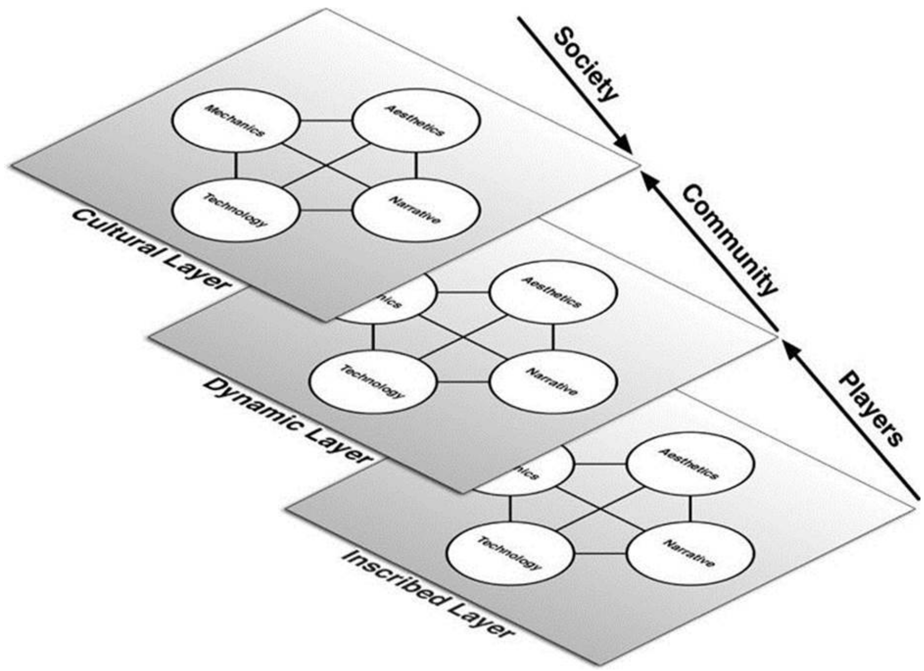

Figure 4: The Layered Tetrad

5.1.1 Conceptual Frameworks

For instance, Sherry and Pacheco presented a matching between computer game genres and educational outcomes [54], which is similar to Ahmad's categorisation of game design elements into educational game design fundamentals: pedagogy, mechanics, aesthetics, story and technology [55].

Yusoff et al. presented a conceptual framework for serious games that gathers elements from Bloom's Taxonomy (cognitive process, knowledge types and learning outcomes) as well as game design concepts such as mechanics, game genre, and achievement and relates them in a structural class diagram [56]. The concrete approach taken to establish these relationships were not revealed, however.

The DPE framework (Design, Play, and Experience) by Winn is based on the widely known MDA framework (Mechanics, Dynamics, Aesthetics) and *"presents a language to discuss design, a methodology to analyze a design, and a process to design a serious game for learning"* [57].

Annetta also presented a framework for serious educational game design focusing on the six aspects of identity, immersion, interactivity, complexity, informed teaching, and instructional design [58]. While emphasising the roles of theses respective aspects, the presented framework did not provide formally graspable steps to integrate them.

Abeele et al. presented a player-centered, iterative, interdisciplinary and integrated framework for serious game design and development [59]. It takes the player's experience into account during the design phase which ensures that the envisioned learning objectives are met. The proposed process generalises the development of serious game design as is often pursued in individual case studies and tightly integrates the evaluation of the effective integration of learning elements. As such, it provides a basic methodological infrastructure for serious game design but does not provide support in terms of the design itself.

Ibanez et al. presented a framework for structuring the design process of serious games [60]. Starting with a teacher's use of software tools like Protégé and MOTOlus to define learning objectives, a simulation of the targeted domain would have to be set up, made interactive, challenges be defined, the overall experience polished and the dissemination handled. Overall, the framework provides structure and solves some technical challenges but does not concern itself with concrete contents, either.

Mitgutsch and Alvarado [61] presented a serious game design assessment framework which describes a formal and conceptual configuration of design elements in relation to the serious game aim and purpose. Six components have been identified: (1) Purpose of the serious game which is explicitly defined, (2) Content and Information contained in the game elements, (3) Fiction and Narrative to introduce a fictional context for the game, (4) Mechanics which define the gameplay possibilities, (5) Aesthetics and Graphics which refers to the audiovisual language in the game, and (6) Framing of the previous aspects in terms of target groups and player literacy.

Rooney presented a theoretical framework for serious game design which considers pedagogy, play and fidelity and their implications for the design process. [62].

Barbosa et al. presented a new methodology of design and development of serious games [63].

Silva presented a practical methodology for the design of educational games [64].

In addition to the shortly introduced, mostly conceptual frameworks on serious game design, some preceding works have attempted to provide a formal process.

The presented frameworks have all attempted to provide a systematic serious game design process but, to the best of our knowledge, there is still a lack of approaches that describe in detail how learning elements and game elements are mapped within a serious game. Since the current work is based on Bloom's Revised Taxonomy, we also mention some works that utilized this taxonomy. Bloom's Revised Taxonomy is an instructional design framework developed to help teachers design useful instructions to meet clear learning objectives [44]. This taxonomy has been investigated in several serious game design studies and is considered the standard framework in instruction design. Haring et. al analysed five psychotherapeutic games and investigate the addressed cognitive processes in their gameplay. These games were approached as educational content and analyzed based on the design description of game designers. They classified the actions taken by the player in the BRT table and they repeated the process for each game. They had a trouble with the knowledge dimension. No consensus could be achieved on how to interpret the game content within the Revised Bloom Taxonomy [65].

Sandham et. al proposed a qualitative and quantitative mapping approach of game mechanics to Bloom's Revised Taxonomy. They defined game elements: objectives, challenges, rewards [66]. Bloom's Revised Taxonomy has also been applied to design business simulations [67] and has been a useful analysis tool to ensure the alignment between learning objectives and activities. However, these methodologies are not generic to permeate the utilization of their design process in other serious games.

5.1.2 Model-driven Frameworks

Unfortunately there are almost none defined for gamification and/or game-based scenario integration in order to reuse their elements. In this article, we propose a contribution that offers a suitable design and smooth integration of game-based scenarios into learning environments by (re)using existing standards and an engineering model-driven approach. Specifically, we use the methodology proposed by the OMG MDA. Several e-learning standards have been proposed, such as LOM, SCORM and IMS-LD. LOM is a standard used for describing interoperable and reusable learning objects in order to be able to exchange information. These standards are not capable of representing all of the dimensions of serious games as they neglect the fun aspects such as the type of the game, motivation and the integration of games in e-learning environments. However, several studies propose metadata schemes based on the LOM standard to describe serious games (LOMFR-SG, SG-LOM). From these two approaches, we propose a generic enriched description of metadata for serious games in order to characterize a generic meta-model. This meta-model represents an independent level of abstraction. Then, according to MDA, we propose a meta-model suitable for our generic Learning Adventure platform, as well as the Claroline Connect one (LMS). Our contribution permits a smooth integration of serious games in e-learning environments. We propose the use of MDA to facilitate the implementation of generic concepts within an existing Serious game platform and e-learning environment [68]

Tang and Hanneghan presented a model-driven framework to support development of serious games for game-based learning composed of nine modules, the Models module is composed of the following three main components [69]: (1) A Game Content Model which represents aspects of serious games such as game objects, their attributes and linkages with art assets, and it is developed by domain experts, (2) a Game Technology Model which represents the serious game software structure independently from the technology platform , and (3) a Game Software Model which represents the software implementation of the serious game specific to a particular platform e.g. XNA, Flash, etc. While their model-driven approach tackles numerous technical challenges, it does not provide help in the design process of an effective serious game.

The development of gamification within non-game information systems as well as serious games has recently gained an important role in a variety of business fields due to promising behavioral or psychological improvements. However, industries still struggle with the high efforts of implementing gameful affordances in non-game systems. In order to decrease factors such as project costs, development cycles, and resource consumption as well as to improve the quality of products, the gamification modeling language has been proposed in prior research. However, the language is on a descriptive level only, i.e., Cannot be used to automatically generate executable software artifacts. In this paper and based on this language, we introduce a model-driven architecture for designing as well as generating building blocks for serious games. Furthermore, we give a validation of our approach by going through the different steps of designing an achievement system in the context of an existing serious game [70].

Serious games have known an enormous outburst during the last decade. These games have the power to use the gamers' immersion in order to foster their motivation and engagement in educational and professional trainings. Unfortunately, the development of serious game scenarios remains an expensive, time consuming business that is exclusively dedicated to computer scientists. Our work aims to solve this problem by introducing a new process capable of building generic reusable and interoperable scenarios. This process is based on MDA (Model Driven Architecture). Its starting point consists in enriching an e-learning standard to define a new meta-model (CIM). This meta-model will manage, assemble and index the scenario components. Starting from CIM model, we define a transformational mechanism to implement playful yet pedagogical scenarios and integrate them within two contexts. The first context focuses on the playful aspect (Unity 3d environment) whereas the second one is purely pedagogical (E-learning platform: claroline connect) [71].

Serious games have become more important in the field of education. The tight connection of education to computer game playing by presenting learning content in a game-like environment creates a better usage experience thus leading to higher usage and potentially better learning outcomes. To create successful serious games, it is necessary to combine programming knowledge and didactical knowledge to properly include learning objectives. Most educators are not able to develop such games on their own due to lack of programming and game design skills. In my dissertation, I am focusing on a solution based on model driven development techniques that shall allow educators to create didactically sound serious games. My idea is it to provide a domain specific modeling language for serious games and a visual modeling tool, which allows the generation of games from visual models [72].

5.1.3 Ontology-based Frameworks

Ontologies are representations, formal names, and definitions of categories, properties, and relationships between concepts, data, and entities substantiating various domains of discourse in computer science and information science. Essentially, an ontology defines a set of concepts and categories that represent the properties of a subject area and how they are related. Ontologies are used in various field of design, among them game design [73] and instructional design [74].

Tang and Hanneghan presented an the Game Content Model, an ontology for documenting serious game design [75] developed from Gagné's nine events of instruction [76]. Particularly, they addressed the game-related terms event, objective, object, player, presentation, rule, scenario, simulation, structure, and theme.

Raies et al. presented an ontology for game play and its application to game-based learning systems that defines rule, action, condition, pedagogic goal, and the game environment [77].

Abou Elfotouh et al. [78] presented a survey and comparison of the existing serious game ontologies, and then [79] presented a Serious Educational Games Ontology which incorporates skill, goal, characterizing goal, game experience, game mechanics, genre, target group, rules, aesthetics, character, balance, and game object.

5.1.4 Metamodel-based Frameworks

By establishing definitions of characters, challenges, contexts, mechanics, and relying on a concrete learning taxonomy, Longstreet and Cooper developed a meta model for serious simulation games [80].

There are several concepts involved in the design of serious games for auditory rehabilitation, such as speech therapy sessions, user capabilities, contexts of use, and serious game design itself. SEGA-ARM is a metamodel that supports the creation of serious games for auditory rehabilitation. A semi-formal UML notation is used to illustrate the proposed solution [81].

6 Emerging Technologies

The question we need to answer when discussing emerging technology in the context of serious games and learning is what role do emerging technologies play in enhancing knowledge mediation, learning, and serious games? What additional value do they provide to the learning process? Would playing a Virtual Reality serious game be better (in terms of knowledge acquisition) than playing a mobile serious game, and if so, in which area, and is the question even relevant? Technology is the practical application of scientific knowledge [82], and it has become ubiquitous. Technology is indispensable in a wide range of fields, including industry, education, medicine, and many others. With technology humans could achieve and reach beyond their built-in capacities and faculties. It is true that with a smartphone and an adequate internet connection, one can access almost all the knowledge humans have accumulated over the course of history. Using augmented reality glasses, we can enrich the real world with other information resources, thereby enhancing navigation, orientation, learning, and so on. By utilizing virtual reality, one can enter a fully developed fantasy world, play with very dangerous lasers, (virtual) electric machinery, use elevators, learn how to build under water, explore space, etc., without experiencing any harmful physical consequences. As technology offers new accessibility options, and since knowledge and learning can take many forms and shapes (visual, auditory, logical, verbal, etc), it is not surprising that technology can enhance learning and enable us to explore new frontiers. The use of cutting-edge technologies is rapidly becoming a part of everyday teaching and learning situations on campus and in schools. More and more teachers and administrators use the term technology integration in educational contexts [83]. In the context of serious games, emerging technologies are not only integrated and used, but these technologies are also a significant influence in the design and deployment of serious games. In this section, we will explore the technologies that have shaped and continue to shape the serious games industry. First, we will discuss deployment technology, where today's serious games are played, and then we will discuss the design and development tools that help build these types of games.

[84]

6.1 Deployment technologies

Because the game industry is so large and prosperous (annual revenues from mobile games such as Pokémon Go consistently exceed one billion dollars [85]), it has made a significant contribution to the development of cutting-edge technologies such as virtual reality and augmented reality. Prior to that, the web and mobile technologies are still widely used and they can be accessed through various media, such as tablets, smartphones, and computers. In addition, learning analytics and artificial intelligence are becoming increasingly important in tracking a learner's learning curve, providing them with tools to monitor their progress, and enhancing their learning experience (e.g. conversational agents [86]). Following, we have grouped these technologies into Web and Mobile, Immersive Technology, Learning Analytics, and Artificial Intelligence.

6.1.1 Web and Mobile technologies

Web refers to the World Wide Web, which is a subset of the Internet consisting of the pages that can be accessed through Web browsers. During the past half century, the web has gone from simple to more advanced technologies: Web 1.0 (static pages, content served from the server's file system) was the first version, and now Web 3.0 version (Semantic Web, Artificial Intelligence, 3D Graphics, etc.) [87]. Due to this permanent progress of the wen, we have now web-based game engines (PlayCanvas, ThreeJs, etc.) for the design and development of games. Serious games are also developed for the web. Firstly, web-based serious games enhance the process of learning at a distance and virtually. These applications are used without downloading, installing, or configuring them, and updates are done automatically. It is possible to access the applications from anywhere and at any time. As web technologies continue to improve, there is less and less difference between desktop applications and web-based serious games [88].

6.1.2 Immersive technologies

It has been noted that personal computers, the Internet, and mobile devices were the three major technological innovation waves, while Virtual Reality (VR) and Augmented Reality (AR) constitute the fourth wave of computing innovation [89]. Virtual reality is continuously growing in popularity due to various factors: its immersive nature; its accessibility; and its affordability [90]. It is found that VR has been adopted in a variety of different fields, including healthcare [91, 92], tele-health [93], education and many more. In the education sector, there are what we call Virtual Museums (VMs) where it is about cultural heritage preservation. A primary concern for museums, heritage sites, and archives, is to promote a better absorption of cultural knowledge through involving learners in the learning process. As a result of this new trend, as well as the digitalisation of the learning environment, Virtual Museums (VMs) are created [94].

6.1.3 Learning Analytics technologies

One challenge for the successful deployment of SEGs is how to measure the learning progress and outcomes achieved by students during their interaction with such environments [95]. Learning analytics is the use of data mining and analysis tools to track and assess student behavior and performance in educational contexts, including the use of educational games. The goal of learning analytics is to provide insights and information that can help educators and students understand and improve the learning process. In the context of educational games, learning analytics can be used to track and assess a wide range of data, including:

- How much time students spend playing the game
- Which game elements and activities students engage with the most
- How students perform on different game tasks and challenges
- Whether students are progressing through the game at a satisfactory rate
- How students' game performance compares to that of their peers

This data can be used to evaluate the effectiveness of the game as a learning tool, and to identify areas for improvement. For example, if students are not spending much time playing the game, or if they are struggling with certain game tasks, this could indicate that the game is not engaging or challenging enough. In such cases, the game design could be adjusted to make it more engaging and effective. Overall, learning analytics can provide valuable insights and information that can help educators and game designers understand and improve the effectiveness of educational games.

6.1.4 Artificial Intelligence technologies

It is necessary to use machine learning techniques in the development of serious games to solve problems such as image recognition, speech-based text recognition, etc. The ability to recognize the emotions of the players is of particular importance, since it enables the identification of game components which cause boredom, fear, or other undesirable emotions [96]. Artificial intelligence (AI) is the use of computer algorithms and data to enable machines to simulate intelligent behavior, such as learning from data, making predictions, or adapting to new situations. In the context of serious games, AI can be used to enhance the game experience and support learning in a number of ways. For example, AI can be used to:

- Enable the game to adapt to the individual abilities and preferences of each player, providing personalized and adaptive learning experiences
- Generate game content and challenges that are tailored to the player's current knowledge and skills, helping to keep the game engaging and challenging
- Analyze player behavior and performance data, in order to provide real-time feedback and support, and to identify areas for improvement
- Simulate intelligent behaviors and responses in game characters and environments, making the game world more believable and immersive
- Analyze and assess the effectiveness of the game as a learning tool, and provide insights and recommendations for game design and development

6.2 Design and Development technologies

We cannot emphasize Serious Game design and development complexity. Frameworks, methodologies are also enhanced with proper design and development tools to ensure the effectiveness of the resulting serious games. Authoring tools for serious game design are more and more developed Design Principles for Serious Games Authoring Tool [97] and in [98] an e-Adventure architecture using the ZeroCouplage Multi-Platform Framework was presented. By coding once, context awareness is automatically generated for mobile game-based learning.

6.2.1 Game Engines

Choosing a suitable software or game engine during the analysis stage is necessary for creating a didactic computer game. Programming languages, multimedia development environments, environments developed expressly for game production, toolkits for e-learning software, and the modification scene are all examples of different sorts of programming tools and alternative methods for producing computer games.[99]

Serious games represent the state-of-the-art in the convergence of electronic gaming technologies with instructional design principles and pedagogies. Despite the value of high-fidelity content in engaging learners and providing realistic training environments, building games which deliver high levels of visual and functional realism is a complex, time consuming and expensive process. Therefore, commercial game engines, which provide a development environment and resources to more rapidly create high-fidelity virtual worlds, are increasingly used for serious as well as for entertainment applications. Towards this intention, the authors propose a new framework for the selection of game engines for serious applications and sets out five elements for analysis of engines in order to create a benchmarking approach to the validation of game engine selection. Selection criteria for game engines and the choice of platform for Serious Games are substantially different from entertainment games, as Serious Games have very different objectives, emphases and technical requirements. In particular, the convergence of training simulators with serious games, made possible by increasing hardware rendering capacity is enabling the creation of high-fidelity serious games, which challenge existing instructional approaches. This paper overviews several game engines that are suitable for high-fidelity serious games, using the proposed framework [100].

1. Unreal Engine has a visual scripting Blueprint framework. Blueprints are graphs that are made from linked blocks. Instead of scripts, the relation generates some logic.

2. Unity game engine that has been developed by Unity Technologies Company. It is the most used engine in the world. It is simple to use and with the most critical attributes. Its development on mobile devices is very fast. The development for games is small and the export process is very simple. Simple to comprehend is the component design of the engine. C scripting is simple and efficient.

3. JMonkey engine is a free game engine that delivers games to all platforms and mobile devices without any expenses. 3D graphics are provided by JMonkey. Although Java programming experience is needed, the open-source engine allows users to extend and modify it to their desires.

4. Libgdx engine is an API development system for Java that works on all supported platforms. The system offers a prototyping atmosphere and fast iterations.

5. Game maker studio 2 Engine is the quickest and most friendly software for cross-platform development. The GameMaker Studio 2 has been fully renovated, enabling developers to build games on a single code basis and to then distribute them on different platforms.

6. Cry engine (CryEngine) is a Crytek Company gamedevelopment platform is developed to support PC platforms and consoles, including Xbox 360

and PlayStation. It allows event scripting, animation, and 3D object development.

7. Marmalade engine was selected for exporting games to several mobile platforms for free and offers the ability to render 3D graphics. Marmalade also helps to develop web applications.

8. OGRE(Object-Oriented Graphics Rendering) engine is a C++ scene-oriented, scalable 3D engine designed to make applications with hardware-accelerated 3D graphics smoother and more accessible to developers. The class library summarizes all specifics of using the framework libraries such as Direct3D and OpenGL and includes a worldwide object and another practical class interface.

9. Construct engine is an HTML5 2D game editor is mainly aimed at non-programmers, who can build games quickly through interactive visualizations. The specific block method to construct is a simple and thrilling way to begin developing games. The syntax of complex languages is not important.

10. Godot engine, with no need to install the engine to start working, supports various operating systems for development and release. Godot also supports the most popular mobile operating systems, but consoles are not supported. Godot has its own GDScript language but supports a lot of other modern languages including C and C++.

7 Summary and Conclusion

8 Acknowledgements

References

[1] D. Djaouti, J. Alvarez, J.-P. Jessel, and O. Rampnoux, "Origins of serious games," in *Serious games and edutainment applications*, pp. 25–43, Springer, 2011.

[2] G. Ardley, "The role of play in the philosophy of plato," *Philosophy*, vol. 42, no. 161, pp. 226–244, 1967.

[3] A. Dennis, "The origins of chess," *American Scientist*, vol. 87, no. 3, pp. 226–237, 1999.

[4] R. Y. Bayeck, "A review of five african board games: Is there any educational potential?," *Cambridge Journal of Education*, vol. 48, no. 5, pp. 533–552, 2018.

[5] A. Hellerstedt and P. Mozelius, "Game-based learning: A long history," in *Irish Conference on Game-based Learning 2019, Cork, Ireland, June 26-28, 2019*, vol. 1, 2019.

[6] B. Sawyer, "Serious games: Broadening games impact beyond entertainment," in *Computer Graphics Forum*, vol. 26, pp. xviii–xviii, Wiley Online Library, 2007.

[7] C. C. Abt, *Serious games.* University press of America, 1987.

[8] J. Alvarez, D. Djaouti, *et al.*, "An introduction to serious game definitions and concepts," *Serious games & simulation for risks management*, vol. 11, no. 1, pp. 11–15, 2011.

[9] K. S. Tekinbas and E. Zimmerman, *Rules of play: Game design fundamentals.* MIT press, 2003.

[10] M. S. Debus, *Unifying game ontology: a faceted classification of game elements.* IT-Universitetet i København, 2019.

[11] B. Gros, M. Valcke, and H. van Keer, "Game-based learning: Present and future," *Educational Technology Research and Development*, vol. 55, no. 4, pp. 431–443, 2007.

[12] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "Game design mechanics: The theory and practice of creating game mechanics and game design abstractions," *Proceedings of the 2011 International Conference on the Foundations of Digital Games*, pp. 24–31, 2011.

[13] K. Squire, "Changing the game: What happens when video games enter the classroom?," *Education Week*, vol. 23, no. 20, pp. 42–45, 2004.

[14] D. Dicheva, C. Dichev, and G. Agre, "State of the art in gamification," *International Journal of Serious Games*, vol. 2, no. 1, pp. 48–62, 2015.

[15] K. Becker, "What's the difference between gamification, serious games, educational games, and game-based learning," *Academia Letters*, vol. 209, 2021.

[16] M. Zyda, "From visual simulation to virtual reality to games," *Computer*, vol. 38, no. 9, pp. 25–32, 2005.

[17] J. Alvarez, O. Rampnoux, J.-P. Jessel, and G. Methel, "Serious game: Just a question of posture," *Artificial & Ambient Intelligence, AISB*, vol. 7, no. 1, pp. 420–423, 2007.

[18] L. Herrewijn and K. Poels, "Rated a for advertising: A critical reflection on in-game advertising," *Handbook of digital games*, pp. 305–335, 2014.

[19] I. Bogost, S. Ferrari, and B. Schweizer, *Newsgames: Journalism at play.* Mit Press, 2012.

[20] M. Schulzke, "Rethinking military gaming: America's army and its critics," *Games and Culture*, vol. 8, no. 2, pp. 59–76, 2013.

[21] D. W. Shaffer, K. Squire, and R. Halverson, *Serious games: Games that educate, train, and inform*, pp. 103–119. MIT Press, 2005.

[22] J. Zeng, S. Parks, and J. Shang, "To learn scientifically, effectively, and enjoyably: A review of educational games," *Human Behavior and Emerging Technologies*, vol. 2, no. 2, pp. 186–195, 2020.

[23] D. Ávila-Pesántez, L. A. Rivera, and M. S. Alban, "Approaches for serious game design: A systematic literature review," *The ASEE Computers in Education (CoED) Journal*, vol. 8, no. 3, 2017.

[24] L. Annetta, *Serious educational games: From theory to practice*. BRILL, 2008.

[25] S. De Freitas, "Are games effective learning tools? a review of educational games," *Journal of Educational Technology & Society*, vol. 21, no. 2, pp. 74–84, 2018.

[26] W. Westera, R. J. Nadolski, H. G. Hummel, and I. G. Wopereis, "Serious games for higher education: a framework for reducing design complexity," *Journal of Computer Assisted Learning*, vol. 24, no. 5, pp. 420–432, 2008.

[27] V. Gonzalez, D. Kulp, L. McFarlane, A. Ritzhaupt, and D. Shaffer, "The effectiveness of simcityedu: Pollution challenge! as a learning tool," *Journal of Educational Computing Research*, vol. 47, no. 3, pp. 341–365, 2012.

[28] C. L. Tan and C. S. Chai, "Using civilization iv to teach world history," *International Journal of Computer-Supported Collaborative Learning*, vol. 5, no. 3, pp. 309–328, 2010.

[29] W. Mestadi, K. Nafil, R. Touahni, and R. Messoussi, "An assessment of serious games technology: *Toward an Architecture for Serious Games Design*," *Int. J. Comput. Games Technol.*, vol. 2018, pp. 9834565:1–9834565:16, 2018.

[30] E. F. Anderson, L. McLoughlin, F. Liarokapis, C. E. Peters, P. Petridis, and S. de Freitas, "Developing serious games for cultural heritage: a state-of-the-art review," *Virtual Real.*, vol. 14, no. 4, pp. 255–275, 2010.

[31] M. Zyda, "From visual simulation to virtual reality to games," *Computer*, vol. 38, no. 9, pp. 25–32, 2005.

[32] F. Liarokapis, S. von Mammen, and A. Vourvopoulos, "Advanced multimodal interaction techniques and user interfaces for serious games and virtual environments," *J. Multimodal User Interfaces*, vol. 15, no. 3, pp. 255–256, 2021.

[33] S. de Freitas and F. Liarokapis, "Serious games: A new paradigm for education?," in *Serious Games and Edutainment Applications* (M. Ma, A. Oikonomou, and L. C. Jain, eds.), pp. 9–23, Springer, 2011.

[34] F. Liarokapis, I. Vidová, S. Rizvic, S. Demesticha, and D. Skarlatos, "Underwater search and discovery: From serious games to virtual reality," in *HCI International 2020 - Late Breaking Papers: Virtual and Augmented Reality - 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19-24, 2020, Proceedings* (C. Stephanidis, J. Y. C. Chen, and G. Fragomeni, eds.), vol. 12428 of *Lecture Notes in Computer Science*, pp. 178–197, Springer, 2020.

[35] L. Nagowah and S. Nagowah, "A reflection on the dominant learning theories: Behaviourism, cognitivism and constructivism.," *International Journal of Learning*, vol. 16, no. 2, 2009.

[36] K. R. Clark, "Learning theories: behaviorism," 2018.

[37] G. Currie, "Cognitivism," *A companion to film theory*, pp. 105–122, 1999.

[38] G. M. Bodner, "Constructivism: A theory of knowledge," *Journal of chemical education*, vol. 63, no. 10, p. 873, 1986.

[39] K. Reid-Martinez and L. D. Grooms, "Constructivism in 21st century online learning," in *Handbook of research on modern educational technologies, applications, and management*, pp. 730–743, IGI Global, 2021.

[40] P. A. Young, *Instructional design frameworks and intercultural models.* IGI Global, 2009.

[41] H. Jung, Y. Kim, H. Lee, and Y. Shin, "Advanced instructional design for successive e-learning: Based on the successive approximation model (sam)," *International Journal on E-learning*, vol. 18, no. 2, pp. 191–204, 2019.

[42] K. Li and J. M. Keller, "Use of the arcs model in education: A literature review," *Computers & Education*, vol. 122, pp. 54–62, 2018.

[43] L. B. Duran and E. Duran, "The 5e instructional model: A learning cycle approach for inquiry-based science teaching.," *Science Education Review*, vol. 3, no. 2, pp. 49–58, 2004.

[44] D. R. Krathwohl, "A revision of bloom's taxonomy: An overview," *Theory into practice*, vol. 41, no. 4, pp. 212–218, 2002.

[45] M. J. Wolf, *The medium of the video game.* University of Texas Press, 2001.

[46] M. Akcaoglu, A. P. Gutierrez, C. B. Hodges, and P. Sonnleitner, "Game design as a complex problem solving process," in *Handbook of research on serious games for educational applications*, pp. 217–233, IGI Global, 2017.

[47] R. Bartle, "Hearts, clubs, diamonds, spades: Players who suit muds," *Journal of MUD research*, vol. 1, no. 1, p. 19, 1996.

[48] C. Klimmt, "Bartle's taxonomy and its application to video game design," *Journal of Computer-Mediated Communication*, vol. 11, no. 3, pp. 830–849, 2006.

[49] B. Magerko and E. Klopfer, "Bartle's taxonomy of play and its relevance to the design of serious games," *Journal of the Learning Sciences*, vol. 17, no. 1, pp. 47–78, 2008.

[50] N. Lazzaro, "The 4 keys 2 fun," *Nicole Lazzaro. Available online: http://www. nicolelazzaro. com/the4-keys-to-fun (accessed on 28 October 2021)*, 2004.

[51] R. Hunicke, M. LeBlanc, R. Zubek, *et al.*, "Mda: A formal approach to game design and game research," in *Proceedings of the AAAI Workshop on Challenges in Game AI*, vol. 4, p. 1722, San Jose, CA, 2004.

[52] B. Cowan and B. Kapralos, "An overview of serious game engines and frameworks," *Recent Advances in Technologies for Inclusive Well-Being*, pp. 15–38, 2017.

[53] M. Saeki and H. Kaiya, "On relationships among models, meta models and ontologies," in *Proceedings of the Proceedings of the 6th OOPSLA Workshop on Domain-Specific Modeling (DSM 2006)*, 2006.

[54] J. Sherry and A. Pacheco, "Matching computer game genres to educational outcomes," *Electronic Journal of Communication*, vol. 16, no. 1, p. 2, 2006.

[55] M. Ahmad, "Categorizing game design elements into educational game design fundamentals," in *Game Design and Intelligent Interaction*, IntechOpen, 2019.

[56] A. Yusoff, R. Crowder, L. Gilbert, and G. Wills, "A conceptual framework for serious games," in *2009 Ninth IEEE International Conference on Advanced Learning Technologies*, pp. 21–23, IEEE, 2009.

[57] B. M. Winn, "The design, play, and experience framework," in *Handbook of research on effective electronic gaming in education*, pp. 1010–1024, IGI Global, 2009.

[58] L. A. Annetta, "The "i's" have it: A framework for serious educational game design," *Review of General Psychology*, vol. 14, no. 2, pp. 105–113, 2010.

[59] V. V. Abeele, B. De Schutter, L. Geurts, S. Desmet, J. Wauters, J. Husson, L. Van den Audenaeren, F. Van Broeckhoven, J.-H. Annema, and

D. Geerts, “P-iii: A player-centered, iterative, interdisciplinary and integrated framework for serious game design and development,” in *Joint Conference on Serious Games*, pp. 82–86, Springer, 2011.

[60] B. C. Ibáñez, B. Marne, and J.-M. Labat, “Conceptual and technical frameworks for serious games,” in *Proceedings of the 5th European conference on games based learning*, pp. 81–87, 2011.

[61] K. Mitgutsch and N. Alvarado, “Purposeful by design? a serious game design assessment framework,” in *Proceedings of the International Conference on the foundations of digital games*, pp. 121–128, 2012.

[62] P. Rooney, “A theoretical framework for serious game design: exploring pedagogy, play and fidelity and their implications for the design process,” *International Journal of Game-Based Learning (IJGBL)*, vol. 2, no. 4, pp. 41–60, 2012.

[63] A. F. Barbosa, P. N. Pereira, J. A. Dias, and F. G. Silva, “A new methodology of design and development of serious games,” *International Journal of Computer Games Technology*, vol. 2014, 2014.

[64] F. G. Silva, “Practical methodology for the design of educational serious games,” *Information*, vol. 11, no. 1, p. 14, 2020.

[65] P. Haring, H. Warmelink, M. Valente, and C. Roth, “Using the revised bloom taxonomy to analyze psychotherapeutic games,” *International Journal of Computer Games Technology*, vol. 2018, 2018.

[66] A. Sandham *et al.*, “Are game mechanics mappable to learning taxonomies?,” in *Proceedings of the 9th European Conference on Games Based Learning*, vol. 1, pp. 753–761, 2015.

[67] T. Ben-Zvi and T. C. Carton, “Applying bloom’s revised taxonomy in business games,” in *Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL conference*, vol. 35, 2008.

[68] N. Aouadi, P. Pernelle, J.-C. Marty, and T. Carron, “A model driven architecture mda approach to facilitate the serious game integration in an e-learning environment,” in *European Conference on Games Based Learning*, p. 15, Academic Conferences International Limited, 2015.

[69] S. Tang and M. Hanneghan, “A model-driven framework to support development of serious games for game-based learning,” in *2010 Developments in E-systems Engineering*, pp. 95–100, IEEE, 2010.

[70] A. Matallaoui, P. Herzig, and R. Zarnekow, “Model-driven serious game development integration of the gamification modeling language gaml with unity,” in *2015 48th Hawaii International Conference on System Sciences*, pp. 643–651, IEEE, 2015.

[71] N. Aouadi, P. Pernelle, C. Ben Amar, and T. Carron, "Mda approach for reusability in serious game and e-learning design," in *International Conference on Web-Based Learning*, pp. 206–212, Springer, 2016.

[72] N. Thillainathan, "A model driven development framework for serious games," *Available at SSRN 2475410*, 2013.

[73] T. Haendler and G. Neumann, "Ontology-based analysis of game designs for software refactoring.," in *CSEDU (1)*, pp. 24–35, 2019.

[74] A. Kalou, G. Solomou, C. Pierrakeas, and A. Kameas, "An ontology model for building, classifying and using learning outcomes," in *2012 IEEE 12th International Conference on Advanced Learning Technologies*, pp. 61–65, IEEE, 2012.

[75] S. Tang and M. Hanneghan, "Game content model: an ontology for documenting serious game design," in *2011 Developments in E-systems Engineering*, pp. 431–436, IEEE, 2011.

[76] R. M. Gagné, R. M. Gagné, *et al.*, *Conditions of learning and theory of instruction.* Holt, Rinehart and Winston, 1985.

[77] K. Raies, K. Rebhi, and M. Khemaja, "Towards ontology of gameplay: application to game based learning systems.," in *AIM SG*, pp. 26–37, 2014.

[78] A. M. Abou Elfotouh, E. S. Nasr, and M. H. Gheith, "Serious educational games' ontologies: A survey and comparison," in *International Conference on Advanced Intelligent Systems and Informatics*, pp. 732–741, Springer, 2016.

[79] A. M. A. Elfotouh, E. S. Nasr, and M. H. Gheith, "Towards a comprehensive serious educational games' ontology," in *Proceedings of the 3rd Africa and Middle East Conference on Software Engineering*, pp. 25–30, 2017.

[80] C. S. Longstreet and K. Cooper, "A meta-model for developing simulation games in higher education and professional development training," in *2012 17th International Conference on Computer Games (CGAMES)*, pp. 39–44, IEEE, 2012.

[81] D. Céspedes-Hernández, J. L. Pérez-Medina, J. M. González-Calleros, F. J. Á. Rodríguez, and J. Muñoz-Arteaga, "Sega-arm: A metamodel for the design of serious games to support auditory rehabilitation," in *Proceedings of the XVI International Conference on Human Computer Interaction*, pp. 1–8, 2015.

[82] https://www.britannica.com/technology/technology. Accessed: 2022-11-22.

[83] D. Hlynka and M. Jacobsen, "What is educational technology, anyway? a commentary on the new aect definition of the field," 2009.

[84] A. Thomas and A. Pfeiffer, "Gallery defender: Integration of blockchain technologies into a serious game for assessment: A guideline for further developments," in *The International Conference on Intelligent Systems & Networks*, pp. 43–53, Springer, 2021.

[85] B. Macias, "What's up with the gaming industry?," *Writing Waves*, vol. 4, no. 2, p. 17, 2022.

[86] F. Bellotti, R. Berta, A. De Gloria, and E. Lavagnino, "Towards a conversational agent architecture to favor knowledge discovery in serious games," in *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, pp. 1–7, 2011.

[87] K. Jacksi and S. M. Abass, "Development history of the world wide web," *Int. J. Sci. Technol. Res*, vol. 8, no. 9, pp. 75–79, 2019.

[88] L. Salvador-Ullauri, P. Acosta-Vargas, and S. Luján-Mora, "Web-based serious games and accessibility: a systematic literature review," *Applied Sciences*, vol. 10, no. 21, p. 7859, 2020.

[89] K. Laeeq, "Metaverse: Why, how and what," *How and What*, 2022.

[90] Educause, "2020 educause horizon report: Teaching and learning edition," 2020.

[91] A. Sipatchin, M. García García, Y. Sauer, and S. Wahl, "Application of spatial cues and optical distortions as augmentations during virtual reality (vr) gaming: The multifaceted effects of assistance for eccentric viewing training," *International Journal of Environmental Research and Public Health*, vol. 19, no. 15, p. 9571, 2022.

[92] S. Condino, M. Gesi, R. M. Viglialoro, M. Carbone, and G. Turini, "Serious games and mixed reality applications for healthcare," 2022.

[93] T. Ong, H. Wilczewski, S. R. Paige, H. Soni, B. M. Welch, B. E. Bunnell, *et al.*, "Extended reality for enhanced telehealth during and beyond covid-19," *JMIR serious games*, vol. 9, no. 3, p. e26520, 2021.

[94] S. Doukianou, D. Daylamani-Zad, and I. Paraskevopoulos, "Beyond virtual museums: adopting serious games and extended reality (xr) for user-centred cultural experiences," in *Visual Computing for Cultural Heritage*, pp. 283–299, Springer, 2020.

[95] I. Daoudi, "Learning analytics for enhancing the usability of serious games in formal education: A systematic literature review and research agenda," *Education and Information Technologies*, pp. 1–30, 2022.

[96] Y. Y. Dyulicheva and A. O. Glazieva, "Game based learning with artificial intelligence and immersive technologies: an overview," in *CEUR Workshop Proceedings*, vol. 3077, pp. 146–159, 2022.

[97] M. Laurent, S. Monnier, A. Huguenin, P.-B. Monaco, and D. Jaccard, "Design principles for serious games authoring tool," *International Journal of Serious Games*, vol. 9, no. 4, pp. 63–87, 2022.

[98] L. Bennis, K. Kandali, and H. Bennis, "An authoring tool for generating context awareness mobile game based learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 17, no. 2, pp. 273–281, 2022.

[99] K. H. Sharif and S. Y. Ameen, "Game engines evaluation for serious game development in education," in *2021 International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, pp. 1–6, IEEE, 2021.

[100] P. Petridis, I. Dunwell, D. Panzoli, S. Arnab, A. Protopsaltis, M. Hendrix, and S. de Freitas, "Game engines selection framework for high-fidelity serious applications," *International Journal of Interactive Worlds*, pp. Article–ID, 2012.