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Proposal of a Conceptual Model for Serious Games Design: A Case Study in Children With Learning Disabilities

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ABSTRACT Serious Games (SG) have a particular ability to motivate and engage in the therapeutic and learning process. There are multiple approaches based on methodologies, frameworks, and models for SG design, which have been proposed based on a specific domain. However, the relationship between the Software Engineering methodologies, with the requirement described in the Game Design Document, and the Instructional Design have not been discussed together. This paper proposes a conceptual model and discusses their relations among those domains, that aims to fill this gap. In order to define the model, those approaches available were analyzed and compared, then suggests several components needed for game design. It describes the primary structure focus on four phases Analysis, Design, Development, and Evaluation, which identifies and validates the roles of all components to achieve the desired educational goals. SG maned ''ATHYNOS'' was developed to help children with learning disabilities. Finally, a case study with three units of analysis points out that ATYHNOS aided participants in the level of concentration, hand-eye coordination, motor skills, and cognitive reinforcement.

INDEX TERMS Serious games, conceptual model for design, game-based learning, ATHYNOS.

I. INTRODUCTION

Serious Game (SG) is an umbrella term applicated for any computer game-based which are designed for educational purposes [1], [2]. Currently, SG is the new trend used as teaching and learning tools, since they are attractive to students (digital natives) [3], [4]. Several benefits of SG have been reported in different case studies with schoolers, such as increasing students' motivation and self-esteem, improving cognitive function, and immediate feedback [5]–[12]. The SG challenge is to expand innovations through powered by emerging technologies like Augmented Reality (AR) or Virtual Reality (VR) that facilitates the constructivist approach. These technologies motivate users to face new experiences according to the individual needs of users.

However, the complexity and sophistication of SG grow as a function of technological progress and requires new digital and audiovisual resources, interaction mechanisms, and narrative [13]. In addition, a significant challenge is the development of SG with technology-enhanced learning approaches, which should be able to quickly capture the player's attention and improve the communication process [14], [15]. A game can enhance the experimentation and simulation manipulated by physical movements using a natural user interface that allows a balance between entertainment and educational objectives.

There are several motivations in the area of SG design. Mainly, they focus on providing a fun experience, an exciting narrative, and an increase in player's motivation. It considers aspects as excellent visual effects and sounds, also this material is comfortable and easy to remember; furthermore, it develops skills that generate interest or curiosity. Also, gameplay into the SG can evoke challenge, suspense, emotion, and empathy with characters that encourage active engagement and sustain learning [16], [17]. Besides, SG offers immediate feedback and adaptability, where players can directly assess their progress (anonymous system), with a less stressful perception. SG allows the adaptation

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to each player's level of difficulty. As a result, SG will be able to improve cognitive functions and emotional. Challenge could achieve a specific goal, integrating problem-solving strategies and increasing their self-efficacy in case of success.

The complexity of the SG development has established several approaches, which involve Software Engineering methodologies [18], [19], design for commercial games through Game Design Document (GDD) [20]–[22], and the environment of game-based learning focused on Instructional Design (ID) [23], [24]. Each one of them establishes diverse activities that can be intertwined to analyze their perspectives to generate a hybrid conceptual model for SG design. Furthermore, this topic has gained increasing attention from researchers, who have reported several benefits such as improving student's motivation, immersive learning experiences, participation, and collaboration in a more meaningful learning setting [25]–[28].

Consequently, the teamwork of SG development should include specialists from different science areas such as software engineers, designers, developers, programmers, artists, teachers, psychologists, pedagogues, and students. Multidisciplinary teams define the specific roles that integrate educational innovation to address the issues in this field. The game should combine episodes of games in synergy with learning, which allows creating an effective SG.

Despite the contributions of researchers' work on SG design, there is still a gap between the approach of the designer using GDD and the developers who use Software engineering methodologies commonly. In this sense, the traditional development methodologies could not guarantee effective coordination and integration in all the related disciplines and present difficulties in this process to achieve a final artifact (SG) [29], [30]. Therefore, it is necessary to establish mechanisms to interweave the technical aspects of Software Engineering with the characteristics of commercial game design and elements of ID. So, they can coexist in an educational environment. Notations and models that fill this gap are necessary to facilitate the design of a successful SG [31]. In this way, a well-designed SG could contribute significantly to children with learning disabilities, or it could serve as a therapeutic reinforcement mechanism in the educational setting.

The rest of the paper is structured as follows. After reviewing the background in Section 2, a summary of the literature review is presented in Section 3. The conceptual model in Section 4 and the analysis results through a case study in Section 5. Finally, conclusions and future work are described.

II. BACKGROUND

Costikyan [32] states that a game is an endogenous reciprocal structure that requires players to reach a specific goal through challenges. This definition has been adapted to the advance of the digital age. In this sense, SG, as a branch of video games, has proposed the concept of computer games designed for a serious purpose that is not pure entertainment. The first scientific work about SG appeared at the end of the decade of the '70s in studies developed by Clark Abt and his colleagues. Abt [33] defined SG as games that have an explicit educational purpose and are not intended to be played mainly for fun.

This definition was partially supported by Michael and Savill-Smith [34], who described SG as games whose primary purpose is not entertainment or fun. Meanwhile, the study carried out by Zyda, [35] describes the SG concept, as a mental competition played on a computer according to specific rules. It uses entertainment to promote training in several areas such as government, education, health, and public policy; defining objectives of strategic communication. Additionally, it incorporates pedagogical aspects (activities that educate or instruct, imparting knowledge or skills) that become an SG.

Game technology is widely available and can incorporate elements of fun and entertainment. It, combined with conventional training and educational approaches, could provide authoritative sources of knowledge transferred in various application domains. In this sense, SG has been mainly used as a tool that offers players a new way of interacting with games. It reinforces the learning process, skills, and knowledge; promoting physical activities, support social-emotional development, and treatment for different educational and physical disorders [36].

The success of SG in educational settings is based on the combination of audiovisual media with immersive technologies that prevail in games, which improves the absorption of information in the student's memory [37], [38]. Recent studies have recognized the benefits of using SG in a variety of contexts [39]–[41]. In work developed by de Freitas [42], the potential of SG to offer a paradigm in training and education for the 21st century is considered. On the other hand, SG has also contributed to the development of skills and abilities on students, such as eye-hand coordination, rapid reaction, multiple attention capacities. Also, it can engage high motivation to achieve critical thinking, relational aptitude, creativity, cooperation, higher tolerance to frustration, adaptability, ability to take risks, problem-solving, and decision-making [43]–[45].

III. RELATED WORKS

For more than two decades, many types of computer games have been developed for educational and training purposes with various levels of success [46]. As technology has evolved, the games have incorporated immersive learning experiences based on adequate strategies [47]–[50]. However, a poorly designed educational game would expose one or more elements of the gameplay. For instance, satisfy the entertainment objectives or sacrifice effective pedagogy to attempt or to keep the game convincing. On the other hand, several educational institutions are immersed in an innovation process, that includes the introduction of digital games in the classroom, as a mechanism to reinforce the learning of their students. In this scenario, SG can show their potential to achieve significant results in the learning process.

Fullerton [25] and Schell [51] mentioned the need to establish methodologies, models, frameworks, and author tools to support the design phase of SG, to ensure its effectiveness in the educational environment through the ludic purpose. Besides, the complexity of the development of SG has established several approaches that involve various processes and activities. Next, several proposals are presented based on the literature analyzed since 2010 (Table 1). Seven methodologies, four frameworks, and six models were identified, which are applied for the SG design. From the examined approaches, five studies considered pedagogical aspects, while only two papers are based on therapeutic elements. Also, four works used experimental design to validate their proposals, either through the case studies or generation of game prototypes. More details are presented below.

A. SOFTWARE ENGINEERING APPROACH

Several contributions have been established from Software Engineering. Connolly [52] and Saavedra *et al.* [19] analyzed how computer games evolved by means of the Software Engineering life cycle. Cano *et al.* [53] proposed the MECONESIS methodology for the SG design for children with hearing disabilities using a Human-Computer Interaction (HCI) approach, which details four phases: analysis, pre-production, production, and post-production. It is based on the unified process of software development, that involves notations like CTT (Concurrent Task Trees) to model the interactions. Unified Modelling Language (UML) to prototype the class diagrams; as well as IMS-LD metadata to describe scenarios, and Business Process Model and Notation (BMPN) to explain processes.

Also, Alsan and Balci [18] presented a GAMED methodology that details the principles, strategies, and procedures that guide step by step the development of an educational game integrated into the software lifecycle. It established 4 phases: a) Game Design (Problem formulation, Game Idea and Game Design); b) Game Software Design (Requirement development, Architecting, and Software Design; c) Game Implementation and Publishing (Programming, integration, and advertising); and d) Game-based Learning and feedback. All stages of each process are proposed for Quality Assurance. These studies stated the benefits of applying SG in learning, which led to positive outcomes in areas like cognition, behavior, affection, and motivation in school environments. Nevertheless, the games need to be evaluated by using appropriate techniques.

Other work [54] includes a methodology based on graphic notation and an interactive narrative for the development of SG, which facilitates teamwork communication. The proposal points out a pre-phase where the design of the educational challenges is selected. It considers a type of game, an initial plan of the story, and the main characters. Sceneries, chapters, and scenes are designed, as well as educational challenges and assessments. Subsequently, the design and collaborative work are carried out in this study.

Saavedra *et al.* [19] established a development process for SG, founded on traditional paradigms of Software Engineering (Requirements, Design, Development, Testing, and Post-mortem). It is integrated with digital learning resources based on pedagogical and technical aspects; that facilitate the teaching-learning process for the students. Additionally, Szczesna *et al.* [55] developed a methodology for designing of SG, where Cognitive-behavior procedures are applied by using psychological tools. It lets participants encounter new feelings and emotions by the time they get entertained. Another study presented by O'Hagan *et al.* [56] specified the adequate procedures for developing games through a set of models that he created. It used hybrid and agile models, with the standard techniques of Software Engineering.

Other researchers have presented results through frameworks and models. For adequate SG designing, Ibrahin and Jaafar [57] combined three factors: game design (usability, multimodal and fun), learning content modeling (syllabus matching), and pedagogy (learning outcomes, motivation theory, self-learning, and problem-solving). Mariais *et al.* [58] defined aspects in the design of Learning Role-Play Game (LRPG) to validate the SG throughout three phases (Initial design, Adjustment to context, and Execution); based on the collection, the scenario exchange, and components of LRPG; considering the actors, rules, and functions. Klapztein and Cipolla [27] described a framework for gamification services. It was developed through the ADR (Action, Design & Research) methodology that establishes four stages: a) problem formulation; b) building, intervention, and evaluation; c) reflection and learning; and d) formalization of knowledge. The proposal focuses on the design of games and services. Besides, this work describes an application implemented through the exposed framework.

Finally, Carvalho *et al.* [59] presented the ATMSG conceptual model for educational games founded on the pedagogical objectives pointed out in the Theory of Activity. It describes how the game components are interrelated with gameplay, as well as the mechanics to achieve the desired pedagogical goals. Three evaluations of studies were implemented for validation with favorable results.

B. ART AND DESIGN APPROACH

The ''Game Design Document'' (GDD) has been created from the Art and Design field. It details all the features and elements of the game. However, the lack of clarity in this document affects how designers present their ideas. Many designers exhibit their works through illustrations or notes without a consolidated structure, which hinders communication between designers and other areas of SG development [60]. Several researchers have proposed activities to document the ideas of game designers, making the communication process easy and practical for the teamwork [20]–[22], [61], [62]. The game development starts with the preparation phase; followed by the design phase, and production phase (with several iterations); and finally, postproduction.

TABLE 1. A summary matrix of SG design components classified by stages/authors (enhanced from [79]).

Stages/ Authors	Components	[53]	[57]	[58]	[27]	[18]	[54]	[19]	[55]	[59]	[66]	[71]	[21]	[22]	[20]	[25]	[23]	[24]
Analysis	Identification of the problem	–	✓	✓	✓	✓	–	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Teaching Objectives	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	–	–	–	–	✓	✓
	Teaching Competence	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	✓	✓
	Learning Tools	–	–	–	–	–	–	–	–	✓	–	✓	–	–	–	–	✓	✓
	User / Player Profile	✓	–	–	✓	✓	✓	–	–	✓	✓	–	✓	✓	✓	✓	✓	–
	User Experience	✓	✓	–	–	–	–	✓	–	–	✓	–	–	–	–	–	–	–
	Quality assurance	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	–	–
	Specification document	✓	–	–	–	✓	–	–	–	–	–	–	✓	✓	✓	✓	–	–
	Therapeutic techniques	–	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	–
	Analysis of tasks	✓	–	–	–	–	✓	–	✓	–	–	–	–	–	–	–	✓	✓
	Rules to automation learning	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓
	Decomposition of skills	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓
	Instructional activities	–	–	–	–	–	–	–	–	✓	–	–	–	–	–	–	✓	✓
Design	Patterns Design	✓	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Game overview	–	–	–	–	–	–	–	–	–	–	–	✓	✓	✓	✓	✓	–
	Narrative	✓	–	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	–
	Game Mechanisms	✓	✓	✓	✓	✓	✓	–	✓	–	✓	✓	✓	✓	✓	✓	–	–
	Requirement Specification	–	✓	–	–	✓	–	–	–	–	✓	✓	–	–	–	–	✓	✓
	Architecture	–	–	✓	–	✓	–	✓	✓	✓	–	–	–	✓		✓	–	–
	Design Prototype	✓	–		–	✓	–	–	–	–	–	–	–	–	–	–	–	–
	Quality assurance	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	–	–
	Document Specification	✓	–	–	–	–	–	✓	–	–	✓	–	✓	✓	✓	✓	–	–
	Assessment Design	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	✓	–
	Technological Evaluation	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓	–
	Emotional Design	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	–
	Academic content planning	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓
	Risk analysis	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	–	–
Development	Game Programming	✓	–	✓	–	✓	–	✓	–	–	–	–	–	–	–	–	–	–
	Application prototype	✓	–	–	–	✓	–	✓	–	–	–	–	–	–	–	–	✓	✓
	Quality assurance	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	–	–
	Specification document	✓	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–
	Game integration	–	–	–	–	✓	✓	–	–	–	✓	–	–	–	–	–	–	✓
Evaluation	Goal Validation	✓	–	✓	–	✓	–	–	–	✓	–	–	–	–	–	–	✓	✓
	Quality assurance	✓	–	–	–	✓	–	✓	–	–	–	–	–	–	–	–	–	–
	Testing	–	–	–	–	–	–	✓	–	–	✓	✓	–	–	–	–	✓	✓
	Feedback	–	–	–	✓	✓	–	–	–	✓	–	–	–	–	–	–	✓	–
	Maintenance	–	–	–	–	✓	–	✓	–	–	–	–	–	–	–	–		✓
	Content review	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓
	Continuous improvement plan	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–

In the preparation phase (analysis), all information about the characteristics, needs, and interests of the target group is collected. The central concept of the game is defined, which is the basis for writing the GDD, and the functional requirements. The videogame genre is selected, then, a storyboard is built based on the preconceived ideas previously discussed

(e. g., the characters style, the environment, the music, among others). The functionality and acceptance of the game are validated through the feedback of the end-user side received in the first test, this stage is known paper prototype [20], [25].

In the *design phase*, the elements that make up the game are defined. The story is developed; script sketches are created to determine the objectives and the context. The principal characters are selected, as well as the overall narrative [20], [63]. As a presentation mechanism, scenarios, and scripts are used to create concepts of the game aspect (e. g., how the characters, the scenes, objects, and sound elements are visualized). Finally, the programming design is established, which describes how the game will be implemented. The programming language and the methodology for the implementation will be selected. Inclusive tasks defined above will aim to generate the GDD.

The *production phase* (development) is similar to the traditional processes of the Software Engineering lifecycle. The GDD and the functional requirements are overlapped into the game scenarios, using programming, interface development, illustration, modeling, animation, and development of sounds.

Finally, in the *post-production phase*, the distribution process consists of publishing or generating copies of the game for sale in different physical/virtual stores. Online and offline marketing is essential to publicize the game and get as many players as possible. The maintenance permits an update to improve task-based on new technological trends of hardware and software.

C. INSTRUCTIONAL DESIGN APPROACH

SG is based on learning theories, which are organized with a set of principles. 1) Constructivism integrates several methods. It could be actor-network, activity, situated learning, problem-based learning, discovery learning, cognitive apprenticeship, case-based learning, and social development. 2) Humanism is based on experimental knowledge. 3) Cognitivism is founded on attribution theory, elaboration theory, cognitive development, and condition of learning. 4) Behaviorism is established on social learning theory, programmed instruction, and direct instruction [64]. The SG design involves several perspectives on learning theories. The game components as well as the learning contents must be discussed regarding these viewpoints.

Another aspect to be considered in the ID is Gagne's Nine events, which can be used according to the game characteristics [65]. These events are recursive and can vary. Sequence and frequency depend on the instructions stated in the game. For example, games gain the players' attention through animations, sound effects, cut scenes, music, and character speech. Feedback must be a constant, intuitive, and adequate environment, and rarely delayed. One of the advantages of including the ID process within the SG design is that the results can be measured which enables the evaluation of the objectives.

There are few models for SG, which integrated the ID with the game development process [23], [24], [66]. This ID aims the consolidation of an adequate, competent, and interactive training within education that adapts to any situation, topic, and audience. The most known ID model is ADDIE (Analyze, Design, Develop, Implement, and Evaluate), which facilitates the complexity of the learning setting [23]. It begins with analyzing the characteristics of students, the content, and the environment, as well as identify required resources. The result will describe a problem with a solution proposal that evaluates the needs of the material and available resources for its application. The *design phase* includes the conduct a task inventory, compose performance objectives and generate testing strategies. The *development phase* details the storyboard, the instructional activities, and the materials of the teacher and student (guidance). The *implementation phase* prepares the learning environment, using the administration system, content review, and technical support for teachers and students. The *evaluation phase* is considered a transversal axis of this model since interpreting the results and review of the activities in each phase. In the case of a prototype, the appropriate adjustments to the expected model are developed [67].

Another proposed model is 4C-ID (Four Components-Instructional Design) [24] applied in educational games and sophisticated learning setting rest on the cognitive load basis [68]. The model contains four non-linear components: learning tasks, supportive information, part-task practices, and just-in-time (JIT) information. The principal design goal is the development of reflective knowledge, which implies the ability to apply automated processes to solve concurrent tasks and problems quickly and effectively. This model also provides a fundamental approach to the analysis of cognitive skills and the design of training to direct these skills.

The methodologies, frameworks, and GDD analyzed for SG design are widely used to strengthen the development of learning competencies, since they allow to improve students' skills (motor, social, and emotional skills and intellectual development aspects) [69]. Likewise, SG could provide an attractive and motivating environment since it allows students to learn from their mistakes. Due to the challenges established according to their level of skills and competencies receiving immediate feedback. It enhances the strengthening of skills in decision-making, collaborative work, and leadership.

Several researchers [55], [58], [70], [71] pointed out the importance of specific components for the SG design, such as clear educational goals, attractive and fun elements, linear narrative, gender, and feedback processes. These components allow the player to meet the established challenges, according to the conceived gameplay. Additionally, the work developed by Carvalho and others [59], [71]–[75] confirmed that the educational objective is the central aspect that should be considered in the initial phase (analysis). Antonaci and Brezinka [76], [77] claimed that motivation is essential in the design of an SG. Nevertheless, a few considerations about the pedagogical features in the game were established.

The evidence lies in the few amounts of studies performed on this critical issue. Klapztein and Cipolla [27] also pointed out that students' skills and knowledge areas ought to be covered for an appropriate SG analysis to achieve the stated goals.

Inclusive approaches were analyzed, focusing on four stages: Analysis, Design, Development, and Evaluation (adapted of ADDIE model), they have been overlapped depending on their characteristics as shown in Table 1. In general, all approaches establish that SG requires a commitment from stakeholders as well as active communication, which ensures a successful development. Another necessary component is a modeling language to detail the SG requirements for a practical design. It is complemented with the verification of compliance of educational objectives.

IV. PROPOSED CONCEPTUAL MODEL

All the studies analyzed so far lead to the conclusion "If SG design is not well-defined, it will not solve the challenges and goals established." Therefore, the SG design process is complex because it integrates various heterogeneous fields of knowledge. Many game developers and Software engineers know little about the Instructional Design, as well as Instructional designers unknown the aspect of the software development life cycle (SDLC) and GDD development. How to combine these three approaches to optimize game-based learning through SG is the challenge. With this background, this paper proposes a model to integrate these points of view to create engaging learning experiences with emerging technologies.

This model is designed to facilitate interactive learning, which incorporates fun and entertainment. It based on learning theories, GDD, SDLC, and instructional processes to meet educational goals considering that SG is a useful learning tool. Part of the challenge is to create immersive learning environments using new technologies like AR/VR. For this proposal of the Conceptual Model for SG design, four main phases were established: Analysis, Design, Development, and Evaluation, as shown in Fig. 1. The details of them are described below.

Analysis: This phase could benefit from software requirement engineering procedures to reduce risks generated by inadequate specifications. It begins with a concept or main idea and specifies the content area/skillset. The document defines (in a few lines) the basic idea of the game, the type or genre, the spectrum of available platforms, the audience, and the risks. On the other hand, every kind of game genre has processes and conventions with their characteristics and strategies. For example, an arcade-genre is associated with puzzle-solving, strategy skills complex thinking, hand-eye coordination, and speed of response. Massively Multiplayer Online Role-Playing Game (MMORPG) allows thousands of players to enter a virtual world simultaneously. Supporting social learning strategies, discovery-based learning, and shared goal setting. An adventure game tends to strengthen evaluation, reflection, and hypothesis testing. Therefore, it is essential to select the game genre that details its characteristics to be designed based on the gameplay interaction.

Later, the user profile characteristics should be known, based on questions such as: Who are the final users? What knowledge, skills, and experiences do the students/users have? What learning styles do they use? Are they comfortable using emerging technologies.? It allows analyzing the age segment, the level of education, experience with video games, physical and mental conditions, skills, availability to play, personality, and the geographical scope (local, national, or international) of the recipients of the game. It includes several languages or cultural features of the region (LATAM, EU, USA, ASIA).

After collecting this information, the next step is to analyze the goals and expected results of the SG. Three categories are considered below. i) Skills, which define specific actions that the player can carry out, ii) Knowledge, focused on conceptual learning and the ability to analyze, synthesize and apply concepts, and iii) Dispositions, which lead the player to a critical self-reflection on beliefs, understanding, and attitudes. Besides, the pedagogical agenda describes general objectives and their a priori conditioning factors, the environment, and the work team. Therefore, it must be established before beginning the development of the SG. This agenda is linked to the pedagogical curricula (e. g., Learning to read, Math, History, Science, among others). It can promote specific causes or values of social, humanitarian, or therapeutic interest. For instance, to help refugees, how to act in case of natural disasters, protection of animals in danger of extinction, or support for learning disabilities.

Within this agenda, the pedagogical objectives must be more granular to be associated with the challenges of the game. Learning strategies must be planned appropriately to serve as a motivating axis within the SG. This process is carried out in an active and critical environment. The construction of identity can be included through avatars in the game, allowing roles to be assumed and decisions to be taken, considering the perspective of the player, based on the theory of self-perception. Learning theories are immersed and will be the central column of game mechanics. For example, Piaget's concept of cognitive disequilibrium describes the experience game players through the process that leads to questions-asking, which could be the key to promote engagement and learning [78]. In the same way, Vygotsky's concept of scaffolding defines the game-designers method used to help players to get successful gameplay [64]. Another aspect of being considered is the condition of the learning needs for the problem-solving using a complex rule/cognitive strategy that must be embedded within the game narrative.

Furthermore, learning strategies define the complexity of the game using cognitive flexibility and meaningful activities, which are close to the player's real environment.

In this sense, levels of difficulty, active learning dynamics, and the use of errors as possible sources of learning and

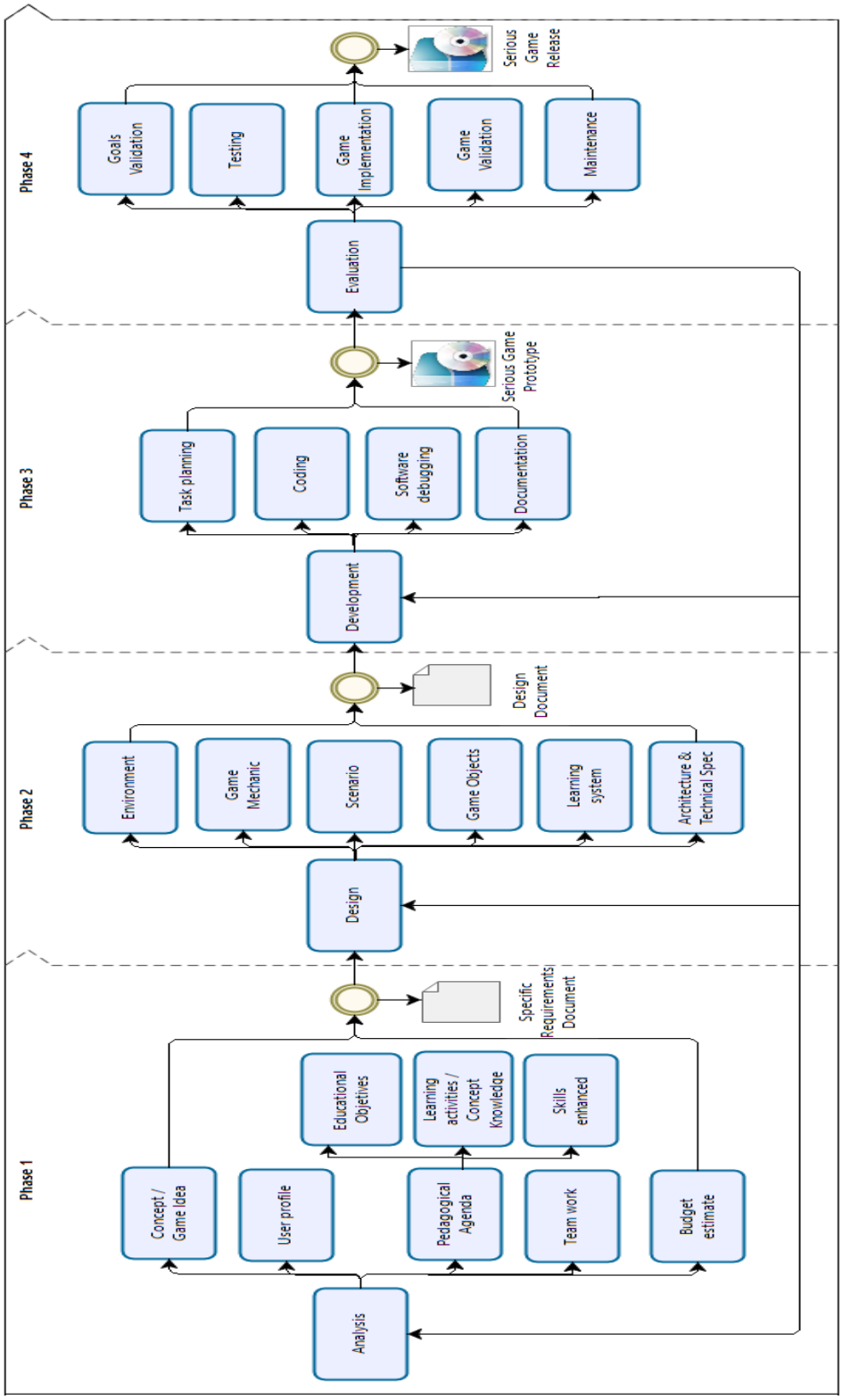

FIGURE 1. Proposed Conceptual Model for SG.

collaborative work can be established. Subsequently, whole pedagogical aspects are integrated into the interaction design and game rules.

The environment defines where the game is intended to be played (classroom, in a space prepared for therapy, or at home) with the possibility of intervention by the teacher,

family members, or therapists. Also, it analyzes the game platform for mobile devices or desktop that interacts with a single-user or multi-user, as well as the entertainment accessories (sounds, video, 2D and 3D images, effects, etc.) The rewards are established during the gameplay and randomization of activities to provide the surprise effect. After that, a work team will be formed, which should include specialists from different areas of science such as software engineers, graphics and game designers, developers, programmers, artists, psychologists, pedagogues, teachers, and students. Altogether, identify the specific roles that integrate educational settings with games episodes in synergy.

For an estimated budget, several factors that involve the cost of developing the SG must be considered. For example, the 2D or 3D graphics components needed, animation required; reusable or non-reusable templates with scenes and scenarios in real environments, the levels of difficulty and the number of players. Therefore, adjustments must be made based on needs and trade-off the way forward.

As a result of this phase, a specification document (2 to 4 pages) is described, which details the functional and non-functional requirements of the SG (Table 2).

TABLE 2. Main components that are collected in the specific requirements document.

Components
• Serious Game Name
• Concept/ Game Idea
▪ Game genre
▪ Player type
▪ Game platform
▪ Technical specification
▪ General game mechanic
• User Profile
▪ Age
▪ Target audience
▪ Group characteristic
• Pedagogical Agenda
▪ Educational objectives
▪ Conceptual knowledge
▪ Learning Goal
▪ Models or learning theories
▪ Skills that will be enhanced
• Teamwork
• Budget estimate

Design: Once the main components have been articulated, the next phase specifies the design requirements needed to achieve the desired goals. It defines the context, behavior, and rules for mastering each challenge/skill. The educational objectives must be grounded in the game narrative. Regarding learning activities, several criteria must be established. For example, a) Organizing the learning material, b) Providing feedback in a formative way of learning, c) Choosing an appropriate language for the game, d) Analyzing the consistency of the learning presentation, and e) Providing interactivity to increase commitment.

In addition, some aspects will be considered as significant when used in therapeutic interventions that will help in learning disabilities. In this sense, the other factors that could be pointed out to develop the game are details. For instance, the application of computer-based activities will allow participants to resolve conflicts, channel negative emotions, and achieve higher social-emotional capacity, providing immediate feedback. The action attempts at personal events are more productive. Repetition is necessary during all interventions since it could help to improve the learning process. Additionally, for the activity to be successful, the learning content must be segmented.

On the other hand, this setting allows determining the main elements in the design phase, that include: Environment, Game mechanic, Scenarios, Game objects, Learning system, and Architecture & Technical Specifications (Fig. 2). Here, it is displayed how the educational objectives are related to the challenges of the game, which are developed implicitly. Its particularities are detailed below.

• *Environment* is the worldgame, which can have physical or virtual constraints of the SG, and it is part of the gameplay context. It promotes an emotional appeal that attracts the attention of the players. Furthermore, it is necessary to define a genre, (e. g., puzzles, role play, racing simulation, flight simulation, adventure, among others) the target audience, and the level of the design which could be defined through the previous market analysis.

• *Game mechanics* is an essential element, which describes the actions that learners/players can do to complete the game goals. It allows building methods and rules designed for the player to interact through challenges, moving characters or objects, rotation systems, and randomizer. Also, it defines the scoring method, rewards or punishments, mobility, among others. The Flow Game is a potent tool for creating content that could become rewarding and engaging. For example, using smart tricks to smoothly guide the player towards the goal and keep them well oriented. Finally, it can be considered the implementation of Artificial Intelligence (AI) algorithms for the automation of internal processes. This component involves activities preprogrammed through non-player character (NPC) that are triggered by actions or dialogue with the player within the SG.

• *Scenario* allows the designer to describe how the game will look. It consists of three layers: representation, services, and interaction. The first layer defines the elements of the scenes, characterization, and context. The scenes represent a setting (e. g., a laboratory, a castle, or a realistic or imaginary representation) as well as establish a configuration that will require a complete workflow in the graphics environment. Also, it is essential to analyze what the role of the characters in the game is, this allows guide the player during the performance (ideal form or blank slate). The last piece is the context, which incorporates elements that could be pictures, props, text, music, art, and so on. The second layer describes a set of services, these are tools that players can use to increase the possibility to play the game longer (e. g., chatting, ranking, leaderboards, badges that prolong the game, among others). The last layer defines the interaction

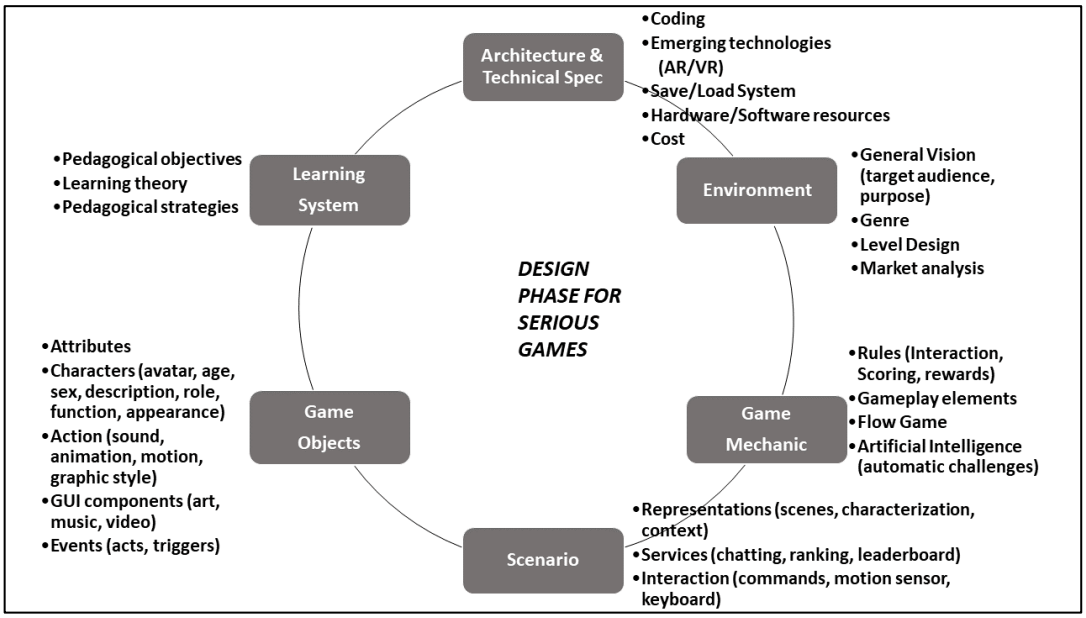

FIGURE 2. Components for Design Phase.

and interface. It describes how the player relates to the game (physical and virtual), and how the game could respond to an intercommunication (commands, input interface through keyboard, mouse, or motion sensors).

• *Game objects* represent a particular object or element included in the environment. They can be able to manipulate physically or virtually during the game. The game object is expressed through characters, actions, GUI components, and events. Characters have a set of characteristics (an avatar, appearance, state, functions, movement activities) and can create actions that describe the aesthetic representation of them. Actions could be the result of the player changing the state or attribute of an object. GUI components are elements used to allow the player to interact through sounds, animations, graphic styles, and motions.

• *The learning system* is a crucial pillar for the construction of knowledge within the SG, which is composed of *educational objectives* and *pedagogical strategies*. The first one is an indispensable tool for teaching, it can be defined by using Bloom's taxonomy. It allows engaging players to interact actively in their learning. Pedagogical strategies define a general teaching method. It can influence instructional design. The combination of both would create a useful educational environment for the SG. In the therapist setting, some intellectual and motor skills can be considered, for instance, motor coordination, reasoning operations, oral expression, concentration, enhancing attention, memory capacity, autonomy, balance, critical thinking, and others.

• *Architecture and technical specifications* describe the components from a procedural perspective. It defines the game architecture that manages the data generated by the client or server. Here are some questions to consider: Is there any new emerging technology that can be integrated into the SG development.? What specifications does the software-development environment need? What will be the software specifications and architecture for SG? What game engine, framework, and development tools will be used? What is the software development kit (SDK) required for emerging/immersive technologies? In what platform will it be released? Which standard security features will be implemented.?

With the technological advancements, tools and applications are available to develop the SG with emerging technologies like AR/VR, that considering capture the user context through the sensors. For this process, it performs transformations, comparing this context with information stored in a database, and generating signals that present digital data (pattern recognition), which produces "augmentations." The equipment/hardware will include video camera/Webcam, storage space for objects, powerful processor, among others. It allows associate real and virtual objects in real-time with a user interface to interact in this setting; and sensors infrastructure capable of identifying movement, position, and direction of players.

In the case of the SG uses a natural user interface (NUI) based on sensors, some strategies for design must be defined. For instance, learn the limits of the sensors (e. g., Sony PlayStation Move, Microsoft Kinect, Oculus), prevent game mechanics that require precise control about sensors. Also, the developer should consider the cognitive load demanded by the player and elements for feedback systems (audio and haptics). Exercise previous and future movements can determine a rhythm in the player actions [80]. Besides, it should be considered whether the SG will use the web environment, a local area network (LAN), or stand-alone.

These elements will allow defining the functionality and features that become part of SG.

All these components of the SG design can be modeled using UML (Unified Modeling Language) notation. Simplified graphic representations of the concepts and objects highlight their main characteristics in the game. For this proposal, the UML profile knows as UP_4EG (UML Profile for Educational Games) proposed by Rodrigues *et al.* [81] could be selected, whose main elements are stereotypes, restrictions, and tagged values. This profile works only with the class diagram because it is one of the most used for software modeling [82]. In order to generate a UP_4EG profile needs to describe each component above and transform it into a package, which handles the different objects and classes.

In the **development phase**, task planning is the process of managing a task as well as the ability to track it. This activity includes using a GANNT chart to ensure that the development process is adequately organized. The requirements described in previous stages begin to be codified by the team of programmers, developers, database analysts, artists, and designers (modelers, animators, sound producers) supported by the technical manager. It is the most extended phase of the SG, and whole development tools must be carefully managed, based on the best programming approach. Software debugging is a necessary process for detecting and fixing problems using methods for code correction. Finally, documentation is done to explain the SG functionality and to discuss essential questions arising between developers and stakeholders.

The **evaluation phase** is another component within the model for SG and must be done continuously in each one to ensure that all elements work correctly. In the testing process, two roles (the expert and end-user) can be used to validate the SG. With the expert, the first task is the validation of the achievement goals, which matches the educational objectives with SG content, and the presence of structuring knowledge. It will contribute to getting the learning/therapy outcomes. Besides, it is necessary to check if the SG is based on one of the learning theories. Assessment can be organized with short-term objectives and in the long-term. For instance, solving the challenge and overcoming the obstacle, fixing all the trials, and achieving the final goal of the game. New forms of evaluation must be designed, which can measure engagement, fun, motivational feedback, summative/formative or individual/collective assessment, among others. After that, Game quality can be evaluated according to the graphics, sounds, and code that are compiled into the game. End-user evaluation is based on the different aspects concerning the ''usability''. For example, it can include cognitive evaluation (challenge, skills, clear goals, ease of doing, innovative, meets demands, competences, among others) and emotional outcomes (enjoyment, boredom, anxiety, control, and independence).

For the game implementation-specific hardware, operating system, plugins, devices, and other components are needed to be well-installed and used in the best conditions to run the SG. Also, it is necessary to provide installation support (guide or instructions) to the player/learner. During the hands-on validation process, the learner performs the training (simulation with serious play measuring and feedback). The instructor/therapist is responsible for accompanying and assisting learners, who are responsible for generating the performance reports, evaluating, and providing feedback to learners together with the SG team manager. Finally, maintenance will allow modifying components of the game system. Its primary purpose is to change and update the SG to expand performance and gameplay or to correct faults.

V. PROPOSAL EVALUATION

The whole process to create of SG used the proposed model as a structure into four phases, which defines a formal description under the needs of a learning setting or therapeutic environment. For this situation, The SG ''ATHYNOS'' was designed for therapeutic activities and cognitive reinforcement.

In the first phase, the requirements concerning the analysis were made. Table 3 shows in detail the components collected in the specific document. The following stage included design. The architecture used in ATHYNOS consists of three main elements: interface, game motor, and report. The interface provides the user's output/input interaction, which sends and receives information to be used by game motor through a NUI. This motor is responsible for the gameplay and connects to the reporting element using a database. The report manages the process to obtain the results, which are accessible to the therapists and experts via an Internet connection. Other components were defined like the environment, game mechanics, the scenarios, and game objects, that described the learning system to children with this learning disabilities.

In the development phase, a desktop platform (Microsoft Windows) and Unity 3D as a powerful game engine were chosen. It combined the functional programming C# with the Vuforia Software Development Kit (SDK) to implement AR. In art and graphic design, Adobe Illustrator allowed the creation of characters, scenes, settings, and environments. Adobe After Effects software was used to generate the prototypes of animations and optimized the presentation of results. Moreover, Adobe Premiere Pro helped the editing of professional videos, and Ableton Live created a music sequence together with Adobe Audition for audio postproduction. These components interacted through a natural user interface with Kinect 2.0 for Windows. All processes must be the best programming practices. Finally, the prototype game was debugging and fixing problems.

For the evaluation of ATHYNOS, a multidisciplinary team was formed. They tested the usability and effectiveness of the game in several pilot tests. The feedback was evaluated and incorporated into the prototypes. The minigames were improved and expanded, until reaching their final version.

ATHYNOS has three minigames; each one was designed to help children with learning disabilities mentioned above. Familiar places and attractions (The Child Pass Festival) in Riobamba city will encourage the player to know about

TABLE 3. Main characteristics of the analysis phase in ATHYNOS.

CHARACTERISTIC	DESCRIPTION		
SG NAME	**ATHYNOS**		
BRIEF DESCRIPTION OF THE GAME IDEA	Athynos reinforces therapies in learning disabilities like dyscalculia, dyspraxia, and ADHD. It is organized into a menu that will visualize three minigames. The worldgame is populated with the cultural learning of the tourist places of Riobamba city. The game does not have the main character, but it is designed with a theme based on "The Child Pass Festival." It takes place during the Christmas season in Riobamba- Ecuador and has seven characters (Clown, Sacha Runa, Devil of Lata, Devil Huma, Danzante, Curiquinge, and Dog). Each player can access to each minigame and meet the challenges established inside of them, through activities. Athynos has a first-person interactive audiovisual display. This SG is designed to support the mathematics skills, capturing the children's attention and improving tasks of organization/planning, bodily-kinesthetics intelligence, hand-eye coordination, and sensory-motor skills. Players will use a PC or laptop, a projector, a motion sensor, and AR cards to interact with the SG, as well as the movements of the hands that are captured through the sensors (Kinect 2.0), allowing a natural user interface. For the recommendation of therapists and psychologists, this game doesn't build to smartphones, because it is considering a distractor element for them. The game requires the therapist administration in a particular setting, thus cannot be played by children independently. SG must include reinforcement, immediate feedback of the performance to the therapist. The measurable variables (successes/errors and execution time) are stored in a database, which allows the analysis of results. The experimental setting will be the public and private therapist center, where the children receive psychological therapies and cognitive reinforcements.		
GAME GENRE	Educational, roleplay, and adventure.		
PLAYER TYPE	Individual		
GAME PLATFORM	Desktop in Windows Operating System, Processor Core I3 and best, RAM: 4GB		
TECHNOLOGICAL SPECIFICATION	Requires Kinect 2.0 sensor for Natural User Interface (NUI) and Tag for Augmented Reality (Vuforia)		
MINI GAME	**Match**	**Shape**	**Missing character**
AGE	7-9 years old	7-9 years old	7-10 years old
TARGET AUDIENCE	Children diagnosed with Dyscalculia	Children with Dyspraxia	Kids diagnosed with ADHD
GAME MECHANIC	The Match minigame reinforces the basic operations of arithmetic. The player chooses a balloon containing a calculation and must match with the result, which is captured using dominoes through a natural interface (sensor). It has three levels of difficulty based on the complexity of the calculation. SG considers the number of successes and errors of each player to obtain a global score, which is analyzed by the therapist.	In this SG has proposed specific game features supporting bodily-kinesthetics and hand-eye coordination. The user must match the figure of the character located in the center of the screen with its correct card showed as body shape. The difficulty depends on missing part of the body shape. The user will earn points for matching successes and time spend to figure it out.	In this minigame, the user must discover which character(s) are missed according to the scenario(s) chosen by the player through the selection of 20 cards that includes an AR tag. The player obtains a score that is computed using the number of successes and errors (performance) and the execution time for finishing the activities. When the player gets the goal, it continues to follow the upper difficulty level.
SKILLS TO BE ENHANCED	Multisensory instruction, working memory, mathematical reinforcement	Fine motor skills, social skills, bodily-kinesthetics, hand-eye coordination	Time management, planning/organization social and sensory-motor skills
RULES	The therapist handles the time and activities performed by the user. The player must complete the tasks/levels before moving on to the next minigame. At the end of each minigame, the number of successes/errors and the time required are saving in the database. Achievements, solve arithmetic problems, find equal forms, rewards, comments, use of strategies, goals establishment, and levels are defined through the gameplay.		

TABLE 3. *(Continued)* **Main characteristics of the analysis phase in ATHYNOS.**

EDUCATIONAL OBJECTIVES	Provide recreational activities that encourage the participation of players in learning activities to improve cognitive skills, fine motor, and social skills, bodily-kinesthetics, hand-eye coordination using SG based on therapies for learning disabilities.
CONCEPTUAL KNOWLEDGE	Grouping of similar or related ideas or sets of attributes. Matching items or contents based on the attributes, not memorization.
LEARNING GOAL	Place content into the appropriate location or connect two objects/facts. Getting familiar with the culture and touristic places of the Riobamba city. Reinforce basic math operations.
MODELS OR LEARNING THEORIES	Constructivism and Cognitive learning theories.
CHECKING RESULTS	Reinforcement, immediate feedback of the performance to the therapist, measurable variables through successes/errors and time spent.
ESTIMATED TIME OF THE GAME	It will be according to therapist planning.
TEAMWORK	Software Engineers, Graphic Designers, Developers, Programmers, Artists, Teachers, Psychologists, Pedagogues, Neuroscientists, and students.
BUDGET ESTIMATE	8.000 USD

the culture local. This SG begins with a tutorial video, that provides a brief detail about how to play it. The following are general characteristics of each game.

A. Match minigame created for children diagnosed with Dyscalculia, which reinforces the basic arithmetic calculation, promotes the motor skills and improve the children's motivation. It consists of a series of activities towards the completion of arithmetic operations. The player chooses a balloon containing a calculation that must match with the corresponding result, which is showed using dominoes cards. The gamer uses the movement hand to complete the action. The minigame has three difficulty levels, each one saved the time spent to solve the activity and the number of successes and errors of each player. The global result is analyzed by the therapist to plan future activities. It is essential to mention that the player passes automatically to the next level (beginner, intermediate, and advanced) and each one has rewards and feedbacks to know if the activity is going well (Fig. 3).

B. Shape minigame was developed for children with Dyspraxia. It helps to improve the movement and coordination, fine and gross motor skills. The player looks in detail the figure of the character located in the center of the screen and must match it with the respective form showed as shape (challenge action). At each level, the child must find the correct way to complete the activity. Three variables (successes, errors, and time) for each quest are automatically recorded into the database (Fig. 4).

C. Missing character minigame is based on cognitive-behavior therapies for kids with ADHD. It helps in inattention, impulsive behavior, concentration difficulties, and working memory. In the minigame, the player selects a game card that contains a tag AR, which is associated with a landscape of Riobamba city, that includes characters of the Child Pass Festival, that is shown on the monitor. The challenge is to check how many characters are presented and find out which one(s) are missing. Then, the player drags and drops. While the child is completing the quests, the game saves automatically the successes/errors obtained, and the time spent to end the activity (Fig. 3).

Experimental research would reveal whether cognitive-behavior therapies performed, and knowledge gained by playing ATHYNOS was significant to improve their skills. It could be evaluated via a case study.

A. DEFINING THE CASE STUDY

This case study used the protocol described by Yin [83] as a research strategy. It allowed to explore the knowledge utilization process and define the appropriate design. This study involved a series of there units of analysis (minigames) in learning disabilities settings. The purpose argues how SG using the proposed model could improve the children's skills. The case study design was selected specific multiple-case, which used small experimental designs to analyze a particular phenomenon (experimental and control groups). It followed a sequential replication design. The first analyzed minigame was completed before the next one was started. The findings were included in the model to improve it. Each subsequent minigame was able to build upon the interpretation of results from previous cases.

The data collection procedure included on-site observation, face-to-face interviews with the key informants, and data saved in registers of SG. This type of evidence was relevant and specified the minimum amount of data to collect. The experts helped to validate proof and correct specific facts. The next step was the analysis, which used an interactive model that consists of quantitative and qualitative tabulations. The case-comparison method took advantage of

FIGURE 3. Screenshot of minigames. a. Missing Character, b. Math, c. Shape.

statistical techniques to compare with the explanation from other facts or components.

B. EXPERIMENT DESIGN

The psychologists identified candidates for this case study, who are working in cognitive-behavior therapies for more than 20 years. These children are receiving therapies for specific learning difficulties (Dyscalculia, Dyspraxia, and ADHD) in public and private centers located in Riobamba city-Ecuador. Their parents wrote a consent for this experiment.

In order to make a comparison, in each unit of analysis (minigame), two groups were classified. The first one was nominated as Control Group (CG), which worked with a traditional therapy method. The second one was called Experimentation Group (EG), which applied ATHYNOS minigames. Educators and therapists were also part of the research team. They directed and coordinated the intervention sessions.

The experimental period was two months by each minigame, where the participants attended two weekly sessions through random selection. Each therapy meeting had a duration of about 15 minutes. The trial was conducted with the use of a laptop (Windows environment), a projector, a tangible device to motion detection (Microsoft Kinect 2.0 sensor), and AR cards. It permits more immersive and interactive actions with little effort by players. According to specialists on learning disabilities, the smartphone was not considered, because of its a distractor for children.

In the beginning, all children were described in detail how to play ATHYNOS minigames. Then, the participants take part in the tangible SG to avoid errors in the experiment. Throughout the sessions, the times spent to solve the assigned activities in the traditional method and using ATHYNOS

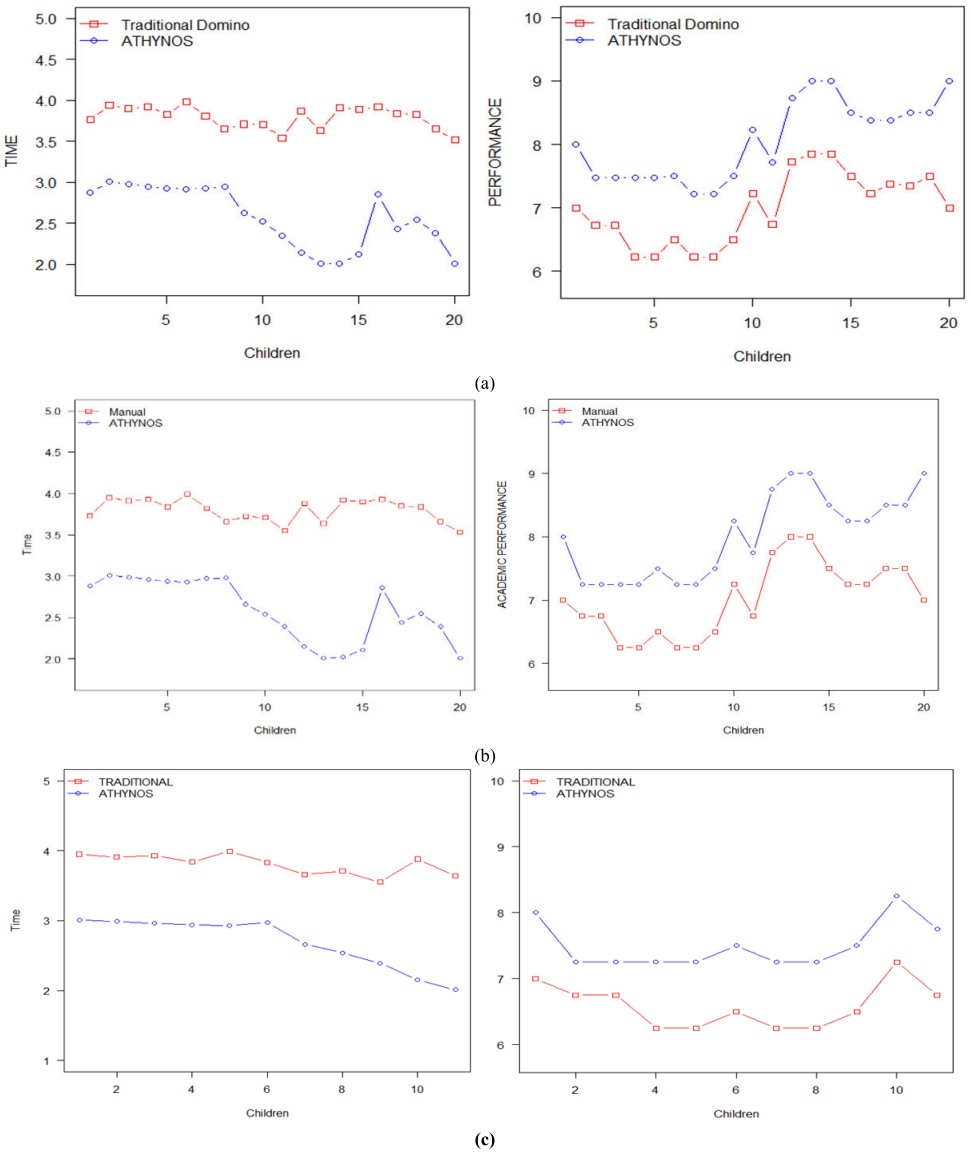

FIGURE 4. Graphic result of the Time and Performance variables between CG and EG. a. Missing Character minigame, b. Math minigame, c. Shape minigame.

were registered. Analogously, for each correct answer (success) is assigned a value of 1 point; otherwise, it had a penalty (error). The following step was to calculate the average score of each participant, considering the scale of 1 to 10 points defined by the Ministry of Education of Ecuador. For this study, this average is known as performance.

Afterward, the statistical open-source software "R" was used to examine in detail. The data distribution was calculated by using the Shapiro-Wilk test. As a result, the time distribution obtained with ATHYNOS was not normal; consequently, the Wilcoxon method was needed. The results are presented in Table 4.

C. EXPERIMENT RESULTS

1) MATCH MINIGAME FOR DYSCALCULIA

The result obtained in p-value 3.337e-05 for the one-tailed is less than a significant level p-value. It confirms children that played ATHYNOS developed the assigned activities in less time compared with the CG. According to the evidence showed, the time spent with the Traditional method of Domino increases meaningfully in the activities' execution. A significant advance in the mathematical reasoning was confirmed in the EG through the analysis of their academic performance. (Fig. 3a).

2) SHAPE MINIGAME FOR DYSPRAXIA

According to Table 4, the p-value 1.085e-04 is less than 0.05. The descriptive analysis corroborates that the execution time is longer when the players work with manual therapy activities. Meanwhile, children that used ATHYNOS were an improvement in their motor level and hand-eye coordination based on performance variable and learning activities. (Fig. 3b).

TABLE 4. Statistical results obtained by participants based on works of [5], [6], [84].

DESCRIPTION	CASE STUDY					
	Dyscalculia		Dyspraxia		ADHD	
PARTICIPANTS	40 children 18 boys, 22 girls (M= 45%; F=55%)		42 children 18 boys, 24 girls (M= 43%; F=57%)		13 children 11 boys, 2 girls (M=85%; F=15%)	
Age	7-9 years old		7-9 years old		7-10 years old	
Age-average	7.95		7.35		8.17	
SD	0.81		0.72		1.29	
GROUP TYPE	Control Group	Exp. Group	Control Group	Exp. Group	Control Group	Exp. Group
Participants	20	20	21	21	13	13
METHOD APPLIED	Traditional Domino	ATHYNOS Match	Traditional Puzzle	ATHYNOS Shape	Traditional Memory game	ATHYNOS Missing Character
Statistical Analysis of TIME (minutes)						
Wilcoxon rank-sum test (two-tailed test)	*p-value = 6.748e-08 <0.05*		*p-value = 1.077e-04 <0.05*		*p-value = 2.835e-06 < 0.05*	
Min	3.520	2.005	3.430	2.010	3.548	2.008
1st Q.	3.688	2.294	3.697	2.330	3.685	2.465
Median	3.830	2.585	3.740	2.605	3.848	2.930
Mean	3.790	2.575	3.798	2.590	3.812	2.686
3rd. Q.	3.902	2.926	3.917	2.945	3.928	2.965
Max	3.980	3.005	3.990	3.010	3.996	3.008
Statistical Analysis of PERFORMANCE (1-10 scale)						
Wilcoxon rank-sum test (two-tailed test)	*p-value = 3.337e-05< 0.5*		*p-value =0.0001085 < 0.05*		*p-value = 0.0001457< 0.05*	
Min	6.225	7.225	6.248	7.250	6.250	7.246
1st Q.	6.495	7.475	6.500	7.250	6.250	7.252
Median	7.000	8.113	7.008	8.125	6.500	7.250
Mean	6.984	8.064	7.013	8.012	6.591	7.500
3rd. Q.	7.406	8.495	7.500	8.500	6.750	7.625
Max	7.850	9.000	8.026	9.000	7.250	8.250

3) MISSING CHARACTER MINIGAME FOR ADHD

As the result, a p-value less than 0.05 is statistically significant, it confirms that participants who played ATHYNOS during the sixteen sessions improved significantly in their daily life functioning across domains of time management and social skills, as well as an improvement in their level of concentration (Fig. 3c). Also, it detected a homogeneity in both groups since the variability of the times and performance values obtained are similar, which points out that children have the same abilities.

This case study was a significant step forward, as it tested and compared the results of the implementation of ATHYNOS in children with learning disabilities (Fig. 4a, 4b, 4c).

VI. CONCLUSION

The attractiveness of videogames among the students younger has sparked many interests in the educational setting. Many empirical types of research have pointed out that games increase student motivation and improve the learning process. However, it is necessary to create a robust model for SG design, which integrates aspects of Software Engineering methodologies with Instructional design and functional requirements described in the Game Design Document. In this sense, the proposed model presents a comprehensive way to design and develop an SG through structured components that are well-defined into four phases.

Compared to other approaches, this work offers a more precise model for the analysis of the agenda educational and elements of Instructional design. It allows linking these components toward the overall learning objectives, performing a decomposition in detail as the game unfolds.

Then, an SG called ATHYNOS was developed based on the proposed model. This game included a natural user interface, based on body movements (use of sensors), as well as AR assistive technology for the learning environment. ATHYNOS helps players in cognitive and motor skills such as motivation, eye-hand coordination, time management, interactivity, and problem-solving, improving selective and focused attention, which were evaluated through a case study and statistical analysis using the local educational environment.

For future research, new tends for evaluation as Game Learning Analytics [85] can provide information regarding

the learning data inside of SG and determine which game components expose greater challenges for users, as well as trace the evolution of successful players' activities. This task will improve the proposed model.

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