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Research article

# Serious educational games for children: A comprehensive framework

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ABSTRACT

*Introduction:* Serious educational games are digital games designed to support teaching or learning objectives that have become popular among children. However, a set of principles is needed to develop a successful educational game. Therefore, this study aimed to provide a comprehensive and valid framework for designing children's serious educational games.

*Methods:* The conceptual framework is developed in two phases. First, a scoping review was conducted in PubMed, Ovid (APA PsycInfo), EMBASE, Scopus, Web of Science, ProQuest, and gray literature on August 1, 2022. Papers in English that reported the serious educational games' principles for children were included. Second, the extracted data from the previous step was reviewed and discussed by the research team to develop the initial framework. Then, it was distributed to 20 experts with relevant knowledge and experience in two rounds to validate and apply their comments within the framework.

*Results:* Of the 12916 papers identified, 15 were included in this study. In the proposed framework named CoDHP, the results were classified into four topics, including (a) content aspects, (b) design requirements, (c) highlighted attributes, and (d) children's preferences. Content aspects comprise four classes (goals and limits, child learning content, learning context, and a long-term program) with 16 principles. Design requirements contain 11 classes (stories and storylines, player characters, game mechanics, interactivity, game challenge, game rules, game help, entertaining games, user interface, accessibility, and setting) with 47 principles, of which 15 are highlighted. Regarding children's preferences for the game elements, various similarities and differences were extracted. For instance, both girls and boys prefer fun and popular games. Based on experts' comments, 21 supplementary principles were recommended to complete the content and design requirements.

*Conclusion:* Game designers or researchers can use the proposed framework as a formative guide to design successful serious games or evaluate children's digital games.

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## 1. Introduction

Video games (VGs) refer to digital or electronic games involving interaction with various platforms, such as computers, mobile phones, joysticks, arcades, consoles, and video display devices (e.g., virtual reality (VR) and mixed reality (MR) headsets) [1]. Nowadays, they are identified as one of the most engaging forms of entertainment and have an essential contribution to the digital future [2]. VGs can be classified into eight genres, namely action, adventure, fighting, puzzle, role-playing, simulation, sport, and strategy games, which often overlap [1]. Serious Games (SGs), among other forms of VGs, are designed for serious purposes besides pure entertainment and can be applied to a broad spectrum of areas, such as the military, business, art, sport, government, healthcare, and education [3].

Using SGs has gained popularity in education and training topics because of three main needs: a new paradigm for learning, innovative interactive technologies to engage learners in problem-solving and capture their attention, and involving them in the curricular content [4,5]. The several advantages of SGs for instructional purposes, such as enhancing the engagement and motivation of the players, achieving optimal attention, improving learners' skills in an enjoyable way, providing an interactive environment, giving quick feedback and progress records, and affording teamwork among learners, led to their popularity in the educational fields [6–8]. Accordingly, many studies have been conducted to show the positive effect of SGs on education and learning [9–11]. For instance, Tubelo et al. revealed that the SGs were an effective tool for improving the students' knowledge of primary healthcare content [10]. Nascimento et al. concluded in their systematic review that SGs can be used as an effective technology for nursing learning compared to other teaching methods [11].

As reported by several researchers, children and young people are increasingly involved in digital games as a normative leisure activity [12–17]. Demonstrating the potential of serious educational games (SEGs) or video game-based learning for children is a timely topic that permeates a lot of educational literature nowadays [1,18,19]. However, these studies focused more on what players learned from digital games or the effectiveness of SGs on learning than on how these games should be designed. For example, Behnamnia et al. reported that the use of digital games in education can have a positive effect on learning and thinking skills, such as critical thinking, creativity, and problem-solving in childhood [18].

The design of SEGs for children faces various challenges, such as developing a fun environment, engaging/motivating players, and achieving the main objective, which must be addressed [20]. To respond to these challenges and design an effective educational game for pedagogical benefits, a wide range of knowledge and skills are required [21]. In other words, understanding the characteristics of game design can lead to the development of a successful game [22]. There are various papers to help researchers in designing SGs; for example, Ávila-Pesántez et al. carried out a systematic literature review to investigate SG design approaches, with an emphasis on phases/stages, pedagogical aspects, and factors [23]. The theoretical model presented by Baptista and Oliveira offers a more concise view of gamification factors [24]. Lameras et al. examined the planning, designing, and implementation of learning design features and game properties by university teachers who are interested in using games for teaching and learning in higher education [25]. Braad et al. outlined different methods, models, and frameworks that can aid in the design and development of serious games [26]. Mayer provided a set of requirements, a conceptual research model that can be used in quasi-experimental study designs, and an evaluation model for game-based learning in specific cases and contexts [27]. Yusoff et al. defined a conceptual framework for SG based on learning theory [28]. However, these studies did not specifically focus on children, nor did they focus on different aspects of SEGs from the viewpoint of related experts, and some of these papers didn't develop a comprehensive framework for designing SGs. There are currently a number of models or frameworks to support the design of SGs for patient children (e.g., children with type 1 diabetes, learning disabilities, and autism spectrum disorder) [29–31], but game requirements for healthy children are different from those for patient children. Conducting a study to show what principles should be considered in designing SEGs for children can help researchers and game developers design successful SEGs. According to the authors' opinions, in addition to the existing literature, the knowledge and experiences of related experts (i.e., game developers, educational experts, and psychologists to comment on design requirements, content aspects, and children's preferences, respectively) can help enrich the principles required for SEGs. Therefore, this work aimed to develop a comprehensive and valid framework for designing children's SEGs in accordance with existing evidence and the knowledge of the mentioned experts, who have at least 7 years of job experience in this field.

## 2. Materials and methods

### 2.1. Ethics statement

The study is a part of a Ph.D. thesis and the Child Abuse & Trauma Research (CHATR) project, which was performed with the approval of the Tabriz University of Medical Sciences Ethics Committee (Numbers: IR.TBZMED.REC.1401.465 and IR.TBZMED.REC.1395.1182).

### 2.2. An overview of the methods' steps

The methodology for this study included two phases. First, a scoping review was carried out to extract principles considered in designing children's SEGs based on the registered and approved proposal of the Ph.D. thesis at Tabriz University of Medical Sciences. Second, an initial conceptual framework was provided based on the results of the previous step. Then it was sent to 20 experts for validation and completion.

Phase 1. Scoping review.

### 2.3. Databases and search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) [32] guided the review process of this study. The completed PRISMA-ScR checklist is available in Appendix **1**. The confirmed search strategy by a librarian expert was conducted in PubMed (Medline and PMC), Ovid (APA PsycInfo), EMBASE, Web of Science, Scopus, ProQuest (Dissertation & Thesis Global Databases), and gray literature (i.e., opengrey.eu, Google Scholar, and manual search) on August 1, 2022. For instance, Table 1 shows the search details in PubMed.

### 2.4. Study eligibility criteria

The eligibility criteria for inclusion in this study were as follows: (a) papers published in English; (b) studies that presented the factors or principles for designing SEGs; (c) studies that aimed at children aged 3–12 years old; (d) studies that reported the children's preferences for SEGs; and (e) peer-reviewed papers. The studies were excluded if (a) they investigated non-digital games; (b) they were focused on patients' children or those with non-typical development, such as exceptional children; (c) they were research protocols; (d) their full texts were not available; and (e) they were letters to the editor.

### 2.5. Study selection and data extraction

The EndNote X8 software was used to manage (i.e., import, screen, and remove papers) the identified references. Three steps were used for the screening of papers: (1) title, (2) abstract, and (3) full text through two authors (AA and PRH). The third author contributed to resolving the disagreements through consultation. After including the eligible papers, the main characteristics were extracted as follows: authors (year), aim, study design, and main findings (see Table 2).

Phase 2. Proposed comprehensive framework and validation.

This phase consisted of two steps, which are described in detail below. In both steps, experts provided written informed consent via Gmail or social networks (i.e., Telegram and WhatsApp) to participate in this study. The consent form included information about the study's purpose and methodology, their role in enhancing and completing the framework, and their right to join or withdraw from the study at any time.

**Step 1**. Determination of the main classes and attributes of the framework.

After conducting a literature review, requirement attributes for SEGs were identified from the included studies. After the initial and independent screening of attributes by the research team with expertise in digital game development (N = 2), psychology (N = 2), and medical education (N = 1), each having more than 8 years of job experience, duplicated principles were eliminated. Subsequently, the main findings from the included studies (see Table 2) were categorized into three primary topics based on the study's objectives: content requirements, design requirements, and children's preferences. Finally, Table 2 and the determined topics, along with their classes and principles, were sent to eight experts for a secondary screening of the extracted data to receive their opinions.

The criteria for selecting experts included having a relevant academic degree (e.g., medical informatics, health information management, information technology, medical education, and psychology) and having at least 7 years of work experience in the SEGs field. The experts were selected using a purposeful sampling method. It is important to note that in Iran, there is no specific academic degree for SGs; therefore, individuals from some fields, such as Health Information Technology/Management (HIT/HIM), Information Technology (IT), multimedia, and medical informatics, work in this area. After receiving the experts' comments, the final principles were retained and entered the validation phase (step 2).

**Step 2**. Validation of the proposed framework

The initial framework, based on the determined topics and attributes, was sent to 20 experts with Ph.D. degrees in related fields, including medical informatics (N = 4), HIM (N = 6), IT (N = 2), medical education (N = 4), and psychology (N = 4) via Gmail to take part in this study. Additionally, a questionnaire consisting of four sections: a brief introduction explaining the study's objectives and its necessity, a guide on how to complete the form, a list of the framework's components (i.e., 3 topics and 105 principles), and a section

**Table 1**
The search strategy in PubMed.

| ID | Search |
|---|---|
| 1 | "Video Games"[MeSH Terms] OR "video game"[Title/Abstract] OR "video games"[Title/Abstract] OR "digital game"[Title/Abstract] OR "digital games"[Title/Abstract] OR "serious game"[Title/Abstract] OR "serious games"[Title/Abstract] OR "computer game"[Title/Abstract] OR "computer games"[Title/Abstract] OR "gamification"[Title/Abstract] OR "exergame"[Title/Abstract] OR "Software-based game"[Title/Abstract] OR "software-based games"[Title/Abstract] OR "Mobile game"[Title/Abstract] OR "mobile games"[Title/Abstract]OR "Mobile-based game"[Title/Abstract] OR "mobile-based games"[Title/Abstract] OR "Video-based game"[Title/Abstract] OR "video-based games"[Title/Abstract] OR "Application-based game"[Title/Abstract] OR "application-based games"[Title/Abstract] OR "app-based game"[Title/Abstract] OR "app-based games"[Title/Abstract] OR "Videogames" [Title/Abstract] OR "online game"[Title/Abstract] OR "Computer-based game"[Title/Abstract] OR "computer-based games"[Title/Abstract] |
| 2 | "Child"[MeSH Terms] OR child*[Title/Abstract] OR "school aged"[Title/Abstract] OR "pre-school"[Title/Abstract] OR "preschool"[Title/Abstract] |
| 3 | "Education"[Mesh] OR "Training Programs" [Title/Abstract] OR Education*[Title/Abstract] OR "Learning"[Mesh] OR Learn*[Title/Abstract] OR train* [Title/Abstract] |
| 4 | #1 AND #2 AND #3 |

**Table 2**
Main characteristics of the included studies.

| Cluster | Authors (year) | Aim | Study design | Main findings |
|---|---|---|---|---|
| **Serious educational games requirements** | Miller and Kocurek [33] | This study presented a set of principles for designing and developing educational games for children. | Data collection: literature review and authors' opinions | • Create developmentally appropriate content<br>• Integrate the theoretical frameworks from the learning science field<br>• Embed learning in socially rich contexts<br>• Develop diverse content<br>• Create a balance between play and real-world learning opportunities |
| | Alfadhli and Alsumait [34] | This paper proposed a set of game-based learning requirements for children. | Data collection: A literature review and authors' and experts' experiences | • Player characters<br>• Storylines and setting<br>• Game rules<br>• Game challenge<br>• Game mechanics and movements<br>• Game resources<br>• Game help and support<br>• User interface |
| | Kemble [35] | A model was proposed for designing children's SEGs | **Step 1 + 2**: Twelve existing models were selected, analyzed, and synthesized.<br>**Step 3:** Items were assigned clusters of similar items and non-duplicate items.<br>**Step 4:** Clustered criteria were synthesized and defined in the new model for health-focused SGs<br>**Step 5:** The resulting set of criteria was applied to five games. | • Define objectives<br>• Provide achievable challenges<br>• Facilitate flow<br>• Balance challenges and achievement<br>• Consider time and culture<br>• Improve children's experience<br>• Provide clear feedback<br>• Provide custom content<br>• Encourages players to construct reasoning and comprehension<br>• Use realistic metaphors for transfer.<br>• Push players to problem solving.<br>• Direct constructed knowledge<br>• Map health behavioral objectives into demonstrations, character interactions, and game environments.<br>• Provide flexible direction for players<br>• Boost players' confidence and competency<br>• Establish a decision guide for scoring |
| | Zarraonandia et al. [36] | This work presented the design method to develop an educational game for helping children | Data collection: A literature review and authors' knowledge | • Game rules model: reward, feedback, goals, debriefing, persistence, mechanics, and socialization<br>• Game scenario model: interface, scenes, character, interaction, context, and services.<br>• Educational game design process (i.e., initial design, refinement and completion, game composition, game profiles definition, game implementation, and reuse and game variant production). |
| | Ahmad and Jaafar [37] | This paper discussed the principles for designing computer game-based learning | Data collection: literature review | The development of a good computer game includes 16 learning principles:<br>• The players should represent their own characters.<br>• The game must provide interactive features.<br>• Actions performed by children must be in accordance with the storyline.<br>• The game must prepare children in risks taking.<br>• Games must have different levels<br>• The players are able to feel the roles<br>• Problems prepared in an orderly manner |

(*continued on next page*)

**Table 2** (*continued*)

| Cluster | Authors (year) | Aim | Study design | Main findings |
|---|---|---|---|---|
| | | | | • A good game offers a set of challenges and reinforcement<br>• A good game offers suitable time and demands<br>• Games should provide meaningful situations<br>• Providing losing but entertaining features in the game leads to improving the skills of players.<br>• Games should encourage players to think<br>• Equipment used in the games is considered smart equipment<br>• Games should encourage players to explore lateral thinking and think of the objective<br>• Games should provide multitasking groups.<br>• The games allow players to participate using pre-competent achievements |
| | Annetta [38]. | This article described lessons learned in designing SEGs for children and presented a framework for designers | Data collection: literature review and authors' knowledge | Six elements of educational game design:<br>• The players identify (e.g., avatar)<br>• Immersion (e.g., through individual identification)<br>• Interactivity (e.g., social communicators)<br>• Increased Complexity<br>• Informed teaching as the feedback and embedded assessments within SEGs<br>• Instructional |
| | Wang et al. [39] | This study determined how to design characters in role-playing games (RPG) educational games | Data collection: authors' knowledge | RPG characters should be designed according to:<br>• The educational goals<br>• The learning content and game plot<br>• Learners' characteristics<br>• The characteristics of the times and culture<br>• Combinations of "education" and "entertainment" |
| | Lieberman et al. [40] | This study examined how digital games could be designed for young children | Data collection: literature review and authors' knowledge | Educational digital games for young children should provide:<br>• Clear, repeatable verbal descriptions and visual presentations of content.<br>• Good stories to engage the child in thinking and maintain their interest.<br>• Characters (role models), who are similar to the child.<br>• Choice and building on success.<br>• Learning in a familiar context.<br>• Adaptive learning through leveled activities and the right amount of challenge.<br>• Provide interactive questioning.<br>• Provide challenges through contests, races, mysteries, problem-solving, simulations, and other goal-oriented activities<br>• Repetition and rehearsal of skills.<br>• Interactive encouragement and help.<br>• Performance feedback.<br>• Social interaction.<br>• Personalization by appearing the child's name and artwork on the screen<br>• Fun, humor, fantasy, and entertainment. |
| | Khine and Shalleh [41] | This study investigated the core attributes of interactive digital games and adaptive use for edutainment | Data collection: literature review and authors' knowledge | • Capturing learner's interest<br>• Anchoring content to reality<br>• Creating learner puzzlement<br>• Providing generous choices |

(*continued on next page*)

**Table 2** (*continued*)

| Cluster | Authors (year) | Aim | Study design | Main findings |
|---|---|---|---|---|
| | | | | • Focusing on the flow (i.e., balancing the challenge of task and skill of learner)<br>• Encouraging collaboration<br>• Promoting creativity |
| **Children's preferences** | de Vette et al. [42] | This study investigated the game preferences of children and translate these into game design. | • Data collection: questionnaire<br>• Samples: 65 children (girls: N = 29, boys: N = 36) | • All participants prefer high dedication and novelty contents.<br>• Significant differences were found between boys and girls in the following domains: discord, rivalry, social, intensity and threat. |
| | Arbianingsih et al. [43] | This study provided a comprehensive picture of what children prefer in computer game for using in health education | • Data collection: a descriptive qualitative approach<br>• Samples: 7 children | • Children prefer an animated and fantasy main character with an attractive appearance.<br>• Bright colors are interesting for children in the game environment.<br>• The types of games selected by children are as follows: activities, rewards and in-game variety. |
| | Osunde [44] | This study investigated some successful digital entertainment games to create educational games for learning. | • An exploratory study<br>• Samples: 32 children (girls: N = 24, boys: N = 8) | • Girls' preferences for SEGs are as follows:<br>Cartoon graphics, moderate control, many fun, using any device, involving player interaction, providing progression rewards, including a definite storyline, using for all ages, not based on character mission, no violence, very popular, bright colour, a human with real scenarios, and game with levels.<br>• Boys' preferences for SEGs are as follows:<br>Photographs graphics, many fun, full control, using specialized devices, single player, providing points rewards, may or may not include a storyline, teenage games-suited for age group, based on character mission, very violent, popular games, dark colors, animals in fantasy scenarios, and lots of action. |
| | Nand et al. [45] | This research extracted the dynamics of popular commercial and motivational games and apply the findings' characteristics to develop engaging educational SGs for children. | • Data collection: questionnaire<br>• Samples: 120 children | The following game attributes were most appealing:<br>• Different levels in the game (challenges)<br>• How many points were scored (feedback)<br>• Realistic graphics: colorful images, real-life characters, and high definition |
| | Nousiainen and Kankaanranta [46] | This study explored the preferences of elementary school children in the design of learning environments. | Data collection: authors studied the development processes of three game-based learning environments or websites for children | • Use familiar UI conventions without risking game-likeness<br>• Visible controls at all times<br>• Visible Game status at all times<br>• Content-rich layouts, little empty space<br>• Realistic appearance<br>• Themes related to real life<br>• Great variety of themes<br>• Much freedom of choice in functionality to allow exploration<br>• Possibility to create something<br>• A main character (a game character or a guiding "mascot") |
| | Kinzie and Joseph [47] | This study investigated the game activity preferences of children. | Data collection: questionnaire | • Children prefer an explorative mode of play<br>• There are gender differences in children's preferences and attitudes toward active, strategic, and creative play modes |

for providing further comments from experts, was sent to them. The selection of expert participants was based on the same inclusion criteria used in the first step. In the initial survey, the experts expressed their general viewpoints on the importance of each principle by selecting from three options: “I disagree," “I have no opinion," and “I agree." Furthermore, they assigned independent scores ranging from 1 to 9 to each principle (1–4 = disagree, 5 = no opinion, 6–9 = agree). They also included their additional suggestions in the final paragraph of the form to complete the identified principles. Some experts requested a face-to-face meeting before submitting their comments. Principles with a final mean score of more than seven were selected; those with a mean score of four to seven were retained for the second round; and principles with a mean score of less than four were excluded. In the second round, the framework along with a response letter, was sent to the 15 experts who participated in the first round for final validation. In each round, experts were given 7 days to submit their comments.

## 3. Results

The initial search yielded 12916 papers from databases and gray literature. A total number of 9468 records remained after removing duplicates in the screening process. The reviewers excluded 9423 records after screening the titles and abstracts. Then, a total number of 45 articles were eligible to be included in the full-text review, of which 30 did not meet the inclusion criteria. Finally, 15 studies were included in the final review (see Fig. 1). Table 2 presents the basic characteristics of the included papers that reported the requirements of SEG development for children based on game design principles and children’s preferences.

Phase 2. The proposed framework for children’s SEGs.

**Step 1**. Determined classes and attributes

Based on the findings of the literature review, 110 attributes were identified from 15 studies for the development of children’s SEGs (see Table 2). A total of 105 principles remained after removing duplicate and similar items during the screening process conducted by the research team. After a secondary screening by eight experts, the same number of principles remained. These 105 principles were categorized into three main classes.

1. Content requirements with 19 attributes.
2. Design requirements with 47 attributes.
3. Children’s preferences with 39 attributes.

**Step 2**. Validated framework

To complete and validate the proposed framework, 15 out of the 20 invited experts participated in this process in two rounds. Table 3 displays the characteristics of the participating experts. In the first round, all items were scored higher than 7 and selected as final principles for designing SEGs. The experts also provided additional suggestions to enhance the content and design aspects of the framework, as follows.

- Devote a separate section within the framework to show the highlighted attributes in designing SGs based on existing literature. In other words, the framework should clearly present the minimum requirements for designing SGs.
- Present the further comments of experts within the framework or in a separate Table to show supplementary principles that were not found in the literature.
- Include some examples in the “Game types" class for activities.
- Specify the more highlighted girls’ and boys’ preferences in SEGs within the framework.
- Incorporate quantitative findings into the children’s preferences section (Topic D)
- Enhance the readability of the framework by employing numbering (i.e., numerical, alphabetical, or Roman) for classes and attributes.
- Include subsets of “performance feedback” (i.e., immediate feedback, seeing and comparing progress, providing text, audio, and video feedback) in the “Interactivity".
- Provide some examples for the “game challenges" class.
- Include an example for the “player character" class.

After incorporating the experts’ minor comments into the framework, they confirmed the updated framework in the second round. Figs. 2–4 illustrate the proposed framework, named CoDHP, based on its four major topics: A) Content aspects; B) Design requirements; C) Highlighted attributes; and D) Children’s preferences. Descriptions of these topics are provided below.

According to the framework, four classes were identified for content aspects, including goals and limits, child learning content, child learning context (i.e., the context where the games should be inserted), and a long-term program. Before designing SEGs, objectives and limitations must be clearly mapped by the designer or the research team. The class of child learning contents comprises 14 principles: considering all developmental aspects of children (e.g., physical, motor, social, cognitive, and emotional domains), illustrating abstract concepts, using simple words and commands, mirroring the language of target children, providing custom contents for players, anchoring content to reality, providing content according to the times and culture, using utility/applicable resources for learning contents, presenting sufficient information based on the main goal, developing diverse content based on the complexity of learning contents, and integrating the theoretical frameworks from the learning field (i.e., some learning theories can be used for educational games), demonstrating clear descriptions, providing repeatable descriptions, and visual presentations as much as possible.

Child learning contexts consist of (1) providing the content in familiar settings (e.g., family and school) and (2) embedding the learning content in socially rich contexts (i.e., enhancing and facilitating the interaction between someone (e.g., peers, parents, or teachers) and a child, especially parent-child interactions). The last class of content aspects is dedicated to long-term programs. It means that the game content must be completed over a period of several weeks. For instance, based on the learning objective, the game content should be divided into chapters and provided over a period of at least one or two weeks.

B) Design requirements for SEGs.

As shown in Figs. 3 and 11 classes with their defined principles were allocated to the design of SEGs: (1) stories and storylines with seven principles, (2) player characters with eight principles, (3) game mechanics and movements with six principles, (4) interactivity features with four principles, (5) game challenges with six principles, (6) game rules with four principles, (7) game help with three principles, (8) fun, humor, fantasy, and entertainment games, (9) user interface (UI) with four principles, (10) accessibility with two principles, and (11) setting with three principles.

C) Highlighted attributes in designing SEGs.

Based on the findings of literature review and experts' opinions, 15 out of the 47 identified principles are highlighted in designing SEGs for children, as follows: (1) having an engaging, clear, and fast-paced storyline, (2) relating the story to the real-world players' experiences, (3) having social interaction (i.e., children can interact with someone, such as peers, parents, or teachers, while engaging in game-based learning), (4) giving feedback on performance (i.e., immediate feedback, seeing and comparing the progress, and providing text, audio, or video feedback), (5) considering learners' characteristics, (6) considering the player's interests, (7) providing

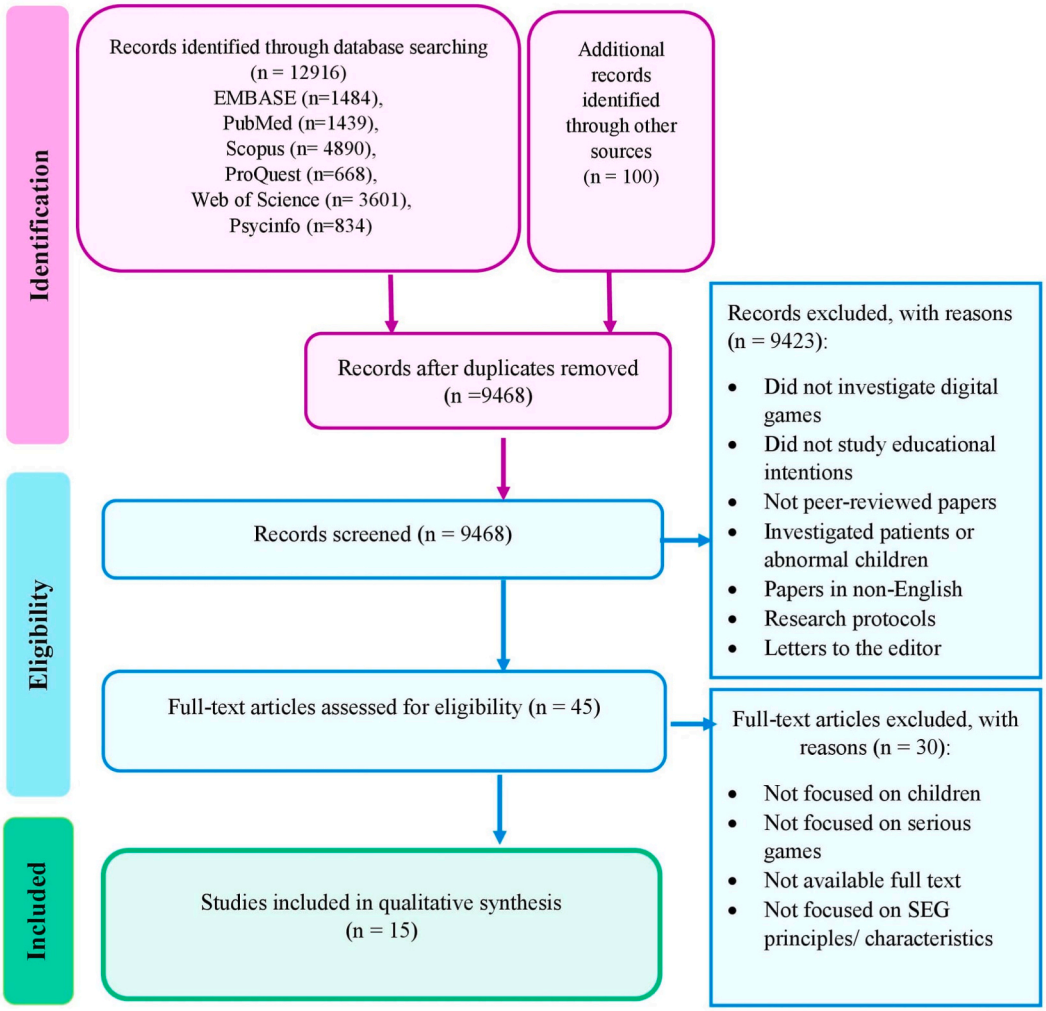


**Fig. 1.** Flowchart for the selection process of the included studies.

personalization options (e.g., the child's avatar, name, and artwork can appear on the screen to stimulate interest and help the child feel special), (8) allowing the players to discover the game storyline, (9) providing achievable challenges, (10) granting rewards (e.g., scores, prizes, and game progress), (11) limiting the player's actions through the game rules, (12) using the minimum amount of mechanics, (13) designing a fun game, (14) considering hardware limitations (accessibility), (15) considering children with disabilities, and (16) culture.

D) Children's preferences in SEGs.

Children's preferences are another part of the proposed framework that is presented according to children's interests in digital games (see Figs. 2–4 for details). For instance, boys and girls prefer high dedication and novelty games. These domains are displayed in the range from 0 to 100 at two extremes in the framework. Dedication refers to the appreciation of a game that requires low self-discipline versus a game that is achievement-oriented, and novelty means the preference for conventional, routine, or real-world versus fantasy, curiosity, and variation in the game's contents. In addition, there are other similarities between girls' and boys' preferences in user interface (UI) navigation, characteristics of the main character, UI appearance, color, content functionality, type of games, content mode, and content theme. However, there are various differences in gender-based preferences among SEGs. For example, girls and boys prefer non-violent and very violent games, respectively. Moreover, there are significant differences between boys and girls in the following domains for content: discord (i.e., peaceful versus violent content), rivalry (i.e., cooperation versus competition), social (i.e., the opposition of the amount of interaction with others between solitary and multiplayer), intensity (i.e., slow and relaxed against fast, intense, and time-pressured), and threat (i.e., stressful game against calm).

## 4. Experts' recommendations

Finally, experts recommended three and eighteen principles based on their knowledge and experiences, respectively, to complement the content aspects and design requirements of SEG (see Table 4 for details).

## 5. Discussion

Serious game applications, particularly for children, have increased in the educational field. In this study, a comprehensive framework was developed based on valid and scientific methods (i.e., a scoping review and the knowledge and experiences of relevant experts) to illustrate what principles are needed in developing SEGs for children.

Determining the content of games is recognized as one of the important aspects of SGs design for children [34,40]. The studies indicated that learning content is identified as a universal attribute in SEGs and plays a crucial contribution in constructing good instructional games [48–50]. These results show the important role of learning content in children's games. In other words, proper integrated learning content can enable children to gain knowledge and enhance their learning performance by playing [51]. Our

**Table 3**
Experts' Demographic characteristics (n = 15).

| Variables | No (%) |
|---|---|
| **Gender** | |
| Male | 9 (60) |
| Female | 6 (40) |
| **Field of education in MSc degrees** | |
| Health Information Technology (HIT) | 4 (26.7) |
| Medical Informatics | 2 (13.3) |
| Multimedia[a] | 4 (26.7) |
| Psychology | 2 (13.3) |
| Medical education | 3 (20) |
| **Field of education in PhD degrees** | |
| Health Information Management[b] (HIM) | 6 (40) |
| Medical Informatics | 4 (26.7) |
| Medical Education | 2 (13.3) |
| Psychology | 2 (13.3) |
| Information Technology | 1 (0.67) |
| **Occupation** | |
| Professor | 4 (26.7) |
| Game developer | 4 (26.7) |
| Psychologist | 2 (13.3) |
| Researcher in educational game | 5 (33) |
| **Job experiences** | |
| 7–10 | 6 (40) |
| 10–15 | 6 (40) |
| ≥15 | 3 (20) |

[a] . There is no Ph.D. degree for multimedia field in Iran.
[b] In Ph.D. degree, the name of HIT was changed to HIM.

proposed framework shows the principles that should be considered in determining the game content for healthy children. In other words, the content requirements for healthy children must be distinguished from those designed for exceptional children because the content aspects are determined by considering the physical and psychological characteristics of children. For instance, Sparapani et al. [29], Shaban and Pearson [30], and Khowaja and Salim [31] developed a specific framework for children with type 1 diabetes, learning disabilities, and autism spectrum disorder, respectively. Content requirements also play an important role in other frameworks that are not focused on children [52,53].For example, Darwesh [52] reported that the concepts of SGs in education consist of six main categories, including scenario, enthusiasm, interactivity, user's traces, scoring, and learning. In his model, content aspects were embedded in the learning layer, but they did not mention the content principles. It should be noted that children's learning must begin with a basic understanding of the fundamentals that they require. Indeed, to design any successful digital game, designers of children's SEGs must first consider the principles of learning content. The content requirements identified in this study can differ based on game goals and user characteristics like age and gender. Based on experts' comments, before designing SEGs, the psychological characteristics of children should be investigated from existing guidelines in this area (e.g., UNESCO and WHO). Additionally, the determined content requires validation through quantitative methods (e.g., standard questionnaires) or qualitative methods (e.g., interviews and expert panels). In other words, using verified and appropriate content can play a crucial role in enhancing the effectiveness of games. Furthermore, to create rich and suitable content for children in educational games, parents' opinions should be taken into consideration because they are more attuned to their children's needs.

A total number of 47 principles have been reported for designing children's SEGs, among which a total number of 15 attributes are highlighted [33–41]. Some of these principles are also mentioned in frameworks that are not created exclusively for children [54,55]. For example, Kalmpourtzis [54] reported five basic elements for a game, i.e., mechanics, aesthetics, story, technology, and pedagogy, which designers should consider at the beginning of the design process. According to Moradi et al. findings, six components, including: educational elements, mechanics, story, aesthetics, dynamic, and proportionality, needs to be used in educational game design [56]. Cheng et al. indicated that SG-assisted learning has been strongly impacted by five key factors: backstory and production, realism, artificial intelligence and adaptivity, interaction, and feedback and debriefing [57].Moreover, Kucher [55] noted that there are five main principles to facilitate the effectiveness of digital game-based learning: (1) interactivity, (2) immersiveness, (3) adaptive problem solving, (4) feedback, and (5) freedom of exploration [58]. Applying design requirements to SEGs can lead to a positive effects through player-motivated interactions. Therefore, game developers should pay attention to them. For instance, the immersive features of VR can be combined with SGs to create games that are more engaging for players [59]. Accordingly, Cheng et al. showed that an immersive SG had a positive correlation with the performance of learning [57]. However, it is difficult to develop SGs that are both entertaining and educational due to the lack of standards on how to design SEGs [60]. Indeed, game designers can provide effective or successful SGs in educational fields when they are familiar with the design aspects. As a result of our findings, a set of game design principles with highlighted items was presented to guide game designers or researchers in developing high-quality SEGs. However, game developers sometimes cannot apply all the design principles due to some existing limitations or challenges; therefore, the highlighted attributes in the proposed framework are useful in identifying the minimum requirements that should be addressed in the design of SGs. For example, using the immersion features of VR-based serious games can face the following challenges: expensive hardware and difficulty using or controlling VR-based SGs, especially in multiplayer games. According to the experts' comments, other principles (see Table 4) should be considered in the design of children's games. These items can help game designers in determining games' characters and stories and enhancing the game features. However, these items are variable based on the game's objectives,

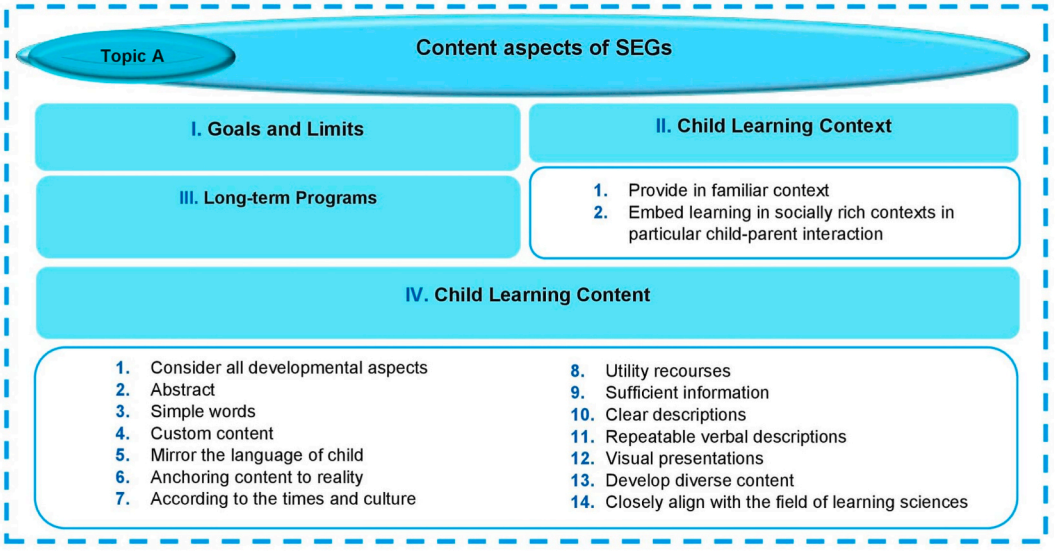


**Fig. 2.** A framework for designing children's serious educational games: Content aspects.


**Fig. 3.** A framework for designing children's serious educational games: Design aspects and Highlighted attributes.

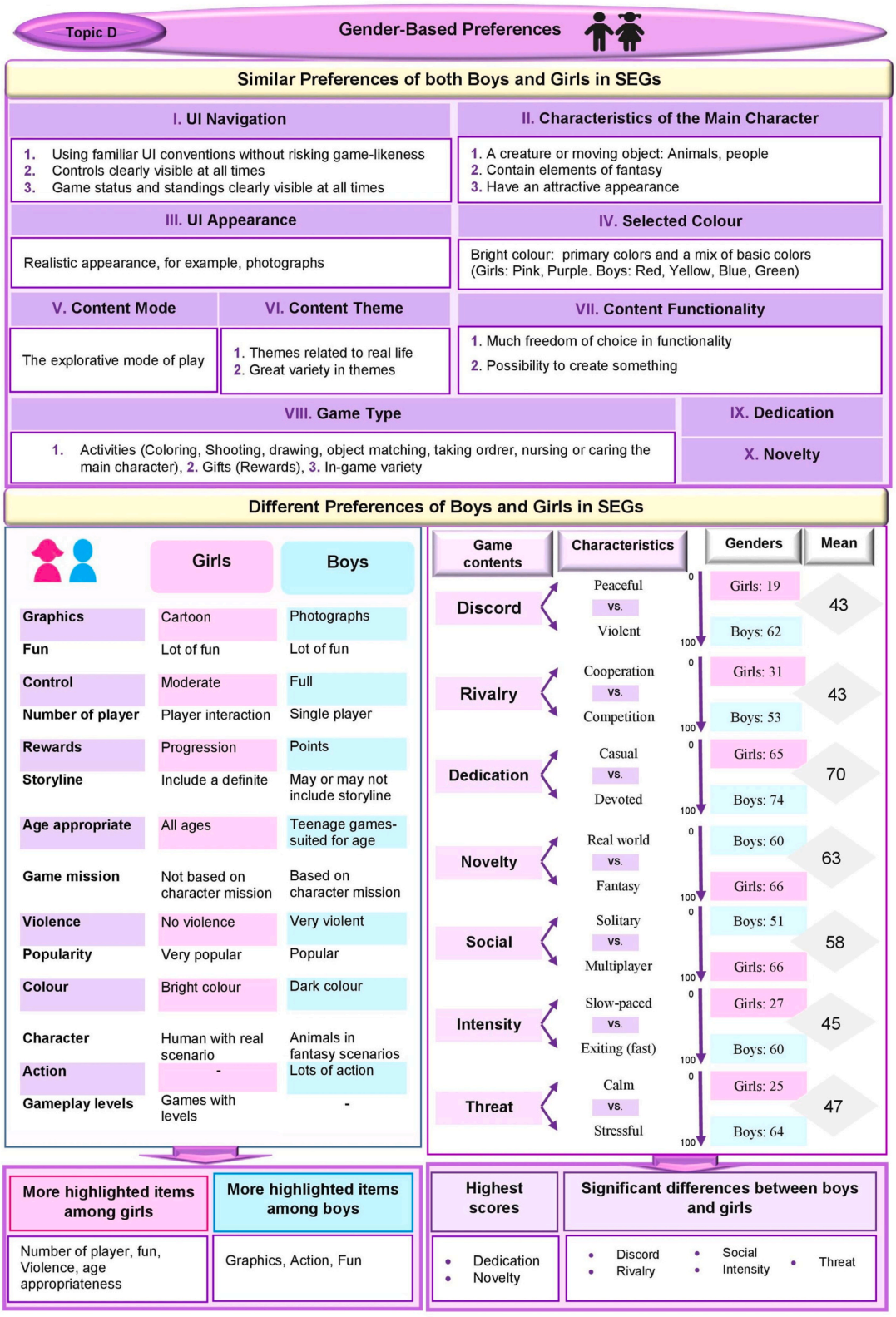


**Fig. 4.** A framework for designing children's serious educational games: Children's preferences.

A) Content aspect of SEGs.

**Table 4**
Experts' recommendations to complete the identified principles in designing SEGs.

| Items | ID | Principles/attributes |
|---|---|---|
| **Content** | 1 | Use the validated content for the game |
| **Aspects** | 2 | Engage parents to receive their needs |
| | 3 | Select the game content based on children's psychological characteristics |
| **Design requirement** | 1 | Use age-appropriate interaction time |
| | 2 | Prefer recognizing than remembering |
| | 3 | Use the meaningful icons as a replacement or help to texts |
| | 4 | Fit the game to the user's level of experience |
| | 5 | Use narrative and short stories to attract players |
| | 6 | Use popular stories to attract players |
| | 7 | Use popular game characters |
| | 8 | Assessment/evaluation the developed SEGs |
| | 9 | Obtain ideas from existing learning environments |
| | 10 | Pay attention to the availability of game platforms |
| | 11 | Present information to player according to their level of development |
| | 12 | Hide features of advanced levels |
| | 13 | Easily control of the game by children |
| | 14 | Use the modular design for the game |
| | 15 | Use principles that both girls and boys prefer/consider gender-based preferences if possible |
| | 16 | Use immersion feature of virtual reality if possible |
| | 17 | Use features of augmented reality if possible |
| | 18 | Allow players to undo and correct mistakes if possible |

users, available facilities, and resources. Understanding user preferences is essential for designing effective SGs [42]. Based on the literature, existing frameworks or models in the field of serious educational games have not taken into account the preferences of players, while paying attention to the interests of users can be very helpful in attracting them to the game [26,61]. Accordingly, González et al. discovered gender and age differences in preferences for device or platform type and game elements [62]. Moreover, Manero et al. indicated that gaming preferences can influence the effectiveness of learning approaches [63]. Indeed, considering the interests or preferences of children has played an important role in designing SEGs. Based on our findings, a number of studies have reported children's preferences in SEGs [42–46]. For example, Osunde stated that both girls and boys like fun and popular games, but their interests are different in terms of the number of players, rewards, storyline, age-appropriate, game mission, violence, color, character, action, and gameplay levels [44]. As demonstrated in the proposed framework, a separate section is dedicated to girls' and boys' preferences in SEGs. According to psychologists' opinions in this study, the extracted preferences of children from the included papers can be used for the majority of children. However, it is undeniable that the interests of all boys and girls may not be the same. In some cases, boys' interests are similar to girls, and vice versa. As shown in Fig. 4, the interests of girls and boys regarding game items are not always absolute zero or 100, but mostly include the range of zero to 100 (e.g., on the scale of discord (peaceful vs. violent), boys give a high score and girls a low score). Researchers of educational video games should consider gender-based preferences to obtain a more accurate insight into their populations. Moreover, preferences can be provided as options for the players. Although following these principles can help in developing effective and successful games, all players' preferences for any purpose cannot be applied due to technical, time, and cost limitations.

## 6. Conclusion

The framework presented here brings together a set of principles for SEGs that are oriented toward designing for children. Educational game designers or researchers can use it as a formative guide to design successful games or evaluate children's SGs. In other words, the proposed framework can help game developers understand the content aspects, design requirements, highlighted principles, gender-based preferences, and helpful recommendations of relevant experts for providing effective children's SEGs. The strengths of this study are its mixture method (i.e., a scoping review and expert knowledge), comprehensive scope, and search of multiple information sources. The major limitation of this paper is that only studies in English-language have been included; therefore, it is recommended that a multilingual research team carry out this work. For future works, the framework can be improved or customized based on more specific factors, such as cultural differences, specific educational topics, specific educational theory, different age groups of children (i.e., children's grades), or the psychological aspects of learners. To respond to the framework customization, researchers should conduct different original articles on how to design SEG for children due to the paucity of studies on these topics.

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## Ethics statement

This study was reviewed and approved by the Tabriz University of Medical Sciences Ethics Committee, with the approval number: [IR.TBZMED.REC.1401.465]. All participants (i.e., involved experts in validation phase) provided informed consent to participate in the study.

## Data availability statement

Data included in article/supplementary material/referenced in article.

## CRediT authorship contribution statement

**Afsoon Asadzadeh:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Data curation, Conceptualization. **Hassan Shahrokhi:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Investigation, Conceptualization. **Behzad Shalchi:** Writing – review & editing, Validation, Resources, Methodology, Conceptualization. **Zhila Khamnian:** Writing – review & editing, Validation, Methodology, Conceptualization. **Peyman Rezaei-Hachesu:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix ASupplementary data

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## References

[1] M.-T. Cheng, J.-H. Chen, S.-J. Chu, S.-Y. Chen, The use of serious games in science education: a review of selected empirical research from 2002 to 2013, Journal of computers in education 2 (3) (2015) 353–375.
[2] C. Wang, L. Huang, A systematic review of serious games for collaborative learning: theoretical framework, game mechanic and efficiency assessment, iJET 16 (6) (2021).
[3] P. Caserman, K. Hoffmann, P. Müller, M. Schaub, K. Straßburg, J. Wiemeyer, et al., Quality criteria for serious games: serious part, game part, and balance, JMIR serious games 8 (3) (2020) e19037, https://doi.org/10.2196/19037.
[4] S. Ciftci, The studies on educational digital games regarding children: a new word analysis approach, TOJET 17 (2) (2018) 158–168.
[5] W. Westera, Why and how serious games can become far more effective: accommodating productive learning experiences, learner motivation and the monitoring of learning gains, Journal of Educational Technology & Society 22 (1) (2019) 59–69.
[6] J.Y.A. Lopez, R.N.N. Huaycho, F.I.Y. Santos, F. Talavera-Mendoza, F.H.R. Paucar, The impact of serious games on learning in primary education: a systematic literature review, International Journal of Learning, Teaching and Educational Research 22 (3) (2023) 379–395.
[7] T. Anastasiadis, G. Lampropoulos, K. Siakas, Digital game-based learning and serious games in education, Int. J. Adv. Sci. Eng. Technol. 4 (12) (2018) 139–144.
[8] S. Adipat, K. Laksana, K. Busayanon, A. Asawasowan, B. Adipat, Engaging students in the learning process with game-based learning: the fundamental concepts, International Journal of Technology in Education 4 (3) (2021) 542–552.
[9] D. Vlachopoulos, A. Makri, The effect of games and simulations on higher education: a systematic literature review, Int J Educ Technol High Educ 14 (1) (2017) 1–33.
[10] R.A. Tubelo, F.F. Portella, M.A. Gelain, M.M.C. de Oliveira, A.E.F. de Oliveira, A. Dahmer, et al., Serious game is an effective learning method for primary health care education of medical students: a randomized controlled trial, Int. J. Med. Inf. 130 (2019) 103944, https://doi.org/10.1016/j.ijmedinf.2019.08.004.
[11] K.G.D. Nascimento, M.B.G. Ferreira, M. Felix, J. Nascimento, S.R.R. Chavaglia, M.H. Barbosa, Effectiveness of the serious game for learning in nursing: systematic review, Revista gaucha de enfermagem 42 (2021) e20200274, https://doi.org/10.1590/1983-1447.2021.20200274.
[12] M.A. Donati, F. Sanson, M. Mazzarese, C. Primi, Assessing video game habits and pathological behaviour in children through a new scale: psychometric properties of the Video-Gaming Scale—for Children (VGS-C), Psychology 10 (16) (2019) 2190.
[13] K.W. Müller, M. Janikian, M. Dreier, K. Wölfling, M.E. Beutel, C. Tzavara, et al., Regular gaming behavior and internet gaming disorder in European adolescents: results from a cross-national representative survey of prevalence, predictors, and psychopathological correlates, Eur. Child Adolesc. Psychiatr. 24 (5) (2015) 565–574, https://doi.org/10.1007/s00787-014-0611-2.
[14] F. Rehbein, S. Kliem, D. Baier, T. Mößle, N.M. Petry, Prevalence of Internet gaming disorder in German adolescents: diagnostic contribution of the nine DSM-5 criteria in a state-wide representative sample, Addiction 110 (5) (2015) 842–851, https://doi.org/10.1111/add.12849.
[15] B. Aydın, A. Oflu, S.S. Yalçın, Evaluation of video game playing status in school-age children with various variables, Turkish archives of pediatrics 56 (2) (2021) 136–140, https://doi.org/10.5152/TurkArchPediatr.2020.20092.

[16] A. Oflu, S.S. Yalcin, Video game use among secondary school students and associated factors, Archivos argentinos de pediatria 117 (6) (2019) e584–e591, https://doi.org/10.5546/aap.2019.eng.e584.
[17] S.S. Yalçın, N. Çaylan, M. Erat Nergiz, A. Oflu, D. Yıldız, Ö. Tezol, et al., Video game playing among preschoolers: prevalence and home environment in three provinces from Turkey, Int. J. Environ. Health Res. 32 (10) (2022) 2233–2246, https://doi.org/10.1080/09603123.2021.1950653.
[18] N. Behnamnia, A. Kamsin, M.A.B. Ismail, S.A. Hayati, A review of using digital game-based learning for preschoolers, Journal of Computers in Education (2022), https://doi.org/10.1007/s40692-022-00240-0.
[19] D.A. Kuipers, G. Terlouw, B.O. Wartena, J.T. van 't Veer, J.T. Prins, J.P.E. Pierie, The role of transfer in designing games and simulations for health: systematic review, JMIR serious games 5 (4) (2017) e23, https://doi.org/10.2196/games.7880.
[20] O. De Troyer, E. Janssens, Supporting the requirement analysis phase for the development of serious games for children, Int J Child Comput Interact 2 (2) (2014) 76–84, https://doi.org/10.1016/j.ijcci.2014.05.001.
[21] A modular approach to support the multidisciplinary design of educational game experiences, in: T. Zarraonandia, P. Díaz, I. Aedo (Eds.), Neural Information Processing, Springer Berlin Heidelberg, Berlin, Heidelberg, 2012 2012.
[22] N.E. Cagiltay, E. Ozcelik, N.S. Ozcelik, The effect of competition on learning in games, Comput. Educ. 87 (2015) 35–41, https://doi.org/10.1016/j.compedu.2015.04.001.
[23] D. Ávila-Pesántez, L.A. Rivera, M.S. Alban, Approaches for serious game design: a systematic literature review, Comput. Educ. J. 8 (3) (2017).
[24] G. Baptista, T. Oliveira, Gamification and serious games: a literature meta-analysis and integrative model, Comput. Hum. Behav. 92 (2019) 306–315.
[25] P. Lameras, S. Arnab, I. Dunwell, C. Stewart, S. Clarke, P. Petridis, Essential features of serious games design in higher education: linking learning attributes to game mechanics, Br. J. Educ. Technol. 48 (4) (2017) 972–994.
[26] Processes and models for serious game design and development, in: E. Braad, G. Žavcer, A. Sandovar (Eds.), Entertainment Computing and Serious Games: International GI-Dagstuhl Seminar 15283, Springer, 2016. Dagstuhl Castle, Germany, July 5-10, 2015, Revised Selected Papers.
[27] I. Mayer, G. Bekebrede, C. Harteveld, H. Warmelink, Q. Zhou, T. Van Ruijven, et al., The research and evaluation of serious games: toward a comprehensive methodology, Br. J. Educ. Technol. 45 (3) (2014) 502–527.
[28] A conceptual framework for serious games, in: A. Yusoff, R. Crowder, L. Gilbert, G. Wills (Eds.), 2009 Ninth IEEE International Conference on Advanced Learning Technologies, IEEE, 2009.
[29] V.C. Sparapani, S. Fels, N. Kamal, L.C. Nascimento, Conceptual framework for designing video games for children with type 1 diabetes, Rev. Latino-Am. Enferm. 27 (2019) e3090, https://doi.org/10.1590/1518-8345.2764.3090.
[30] A learning design framework to support children with learning disabilities incorporating gamification techniques, in: A. Shaban, E. Pearson (Eds.), Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems, 2019.
[31] K. Khowaja, S.S. Salim, A framework to design vocabulary-based serious games for children with autism spectrum disorder (ASD), Univers. Access Inf. Soc. 19 (4) (2020) 739–781.
[32] A.C. Tricco, E. Lillie, W. Zarin, K.K. O'Brien, H. Colquhoun, D. Levac, et al., PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation, Annals of internal medicine 169 (7) (2018) 467–473, https://doi.org/10.7326/m18-0850.
[33] J.L. Miller, C.A. Kocurek, Principles for educational game development for young children, J. Child. Media 11 (3) (2017) 314–329.
[34] Alfadhli S, Alsumait A, editors. Game-based Learning Guidelines: Designing for Learning and Fun2016. doi:10.1109/CSCI.2015.37.
[35] W.R. Kemble, A Proposed Model for Designing Children's Health-Focused Serious Games [M.F.A.], Iowa State University, Ann Arbor, 2014.
[36] T. Zarraonandia, P. Diaz, I. Aedo, A modular approach to support the multidisciplinary design of educational game experiences. NEURAL INFORMATION PROCESSING, ICONIP, 2012, pp. 560–567. PT IV2012.
[37] I. Ahmad, A. Jaafar, Computer Games: Implementation into Teaching and Learning I2012, UNIVERSITI KEBANGSAAN MALAYSIA TEACHING AND LEARNING CONGRESS, 2011, pp. 515–519.
[38] L.A. Annetta, The "I's" have it: a framework for serious educational game design, Rev. Gen. Psychol. 14 (2) (2010) 105–112, https://doi.org/10.1037/a0018985.
[39] The study of characters design in PRG educational games, in: Y. Wang, F. Wang, Y. Cheng, C. Zhao, Z. Zheng (Eds.), 2009 2nd IEEE International Conference on Computer Science and Information Technology, IEEE, 2009.
[40] D.A. Lieberman, M.C. Fisk, E. Biely, Digital games for young children ages three to six: from research to design, Comput. Sch. 26 (4) (2009) 299–313, https://doi.org/10.1080/07380560903360178.
[41] M.S. Khine, M. Shalleh Bin Suja'Ee, Core attributes of interactive computer games and adaptive use for edutainment. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2008, pp. 191–205.
[42] de Vette AFA, Tabak M, Vollenbroek-Hutten MMR, editors. How to Design Game-Based Healthcare Applications for Children? A Study on Children's Game Preferences2018. doi:10.5220/0006584804220430.
[43] Rustina Y. Arbianingsih, T. Krianto, D. Ayubi, Developing a health education game for preschoolers: what should we consider? Enfermería clínica 28 (2018) 1–4, https://doi.org/10.1016/S1130-8621(18)30025-1.
[44] O.J. Osunde, A Study into the Characteristics of Game-Based Learning Software that Appeal to 11-14 Year Old Girls [Ph.D.], University of Greenwich (United Kingdom), Ann Arbor, 2017.
[45] K. Nand, N. Baghaei, J. Casey, Play & learn: designing engaging educational games for children, Int J Cogn Technol 18 (1) (2013) 28–35.
[46] T. Nousiainen, M. Kankaanranta, Exploring children's requirements for game-based learning environments, Adv Hum Comput 2008 (2008).
[47] M.B. Kinzie, D.R. Joseph, Gender differences in game activity preferences of middle school children: implications for educational game design, Educ. Technol. Res. Dev. 56 (2008) 643–663.
[48] S.A. Ishak, R. Din, U.A. Hasran, Defining digital game-based learning for science, technology, engineering, and mathematics: a new perspective on design and developmental research, J. Med. Internet Res. 23 (2) (2021) e20537, https://doi.org/10.2196/20537.
[49] S.A. Ishak, R. Din, U.A. Hasran, Beyond play: conceptualising the capability of a good digital game to stimulate interest in STEM, International Journal of Learning, Teaching and Educational Research 20 (10) (2021).
[50] L. Crescenzi-Lanna, The developmental appropriateness of digital games and its impact on young children's enjoyment and playtime, International Journal of Child-Computer Interaction 33 (2022) 100480, https://doi.org/10.1016/j.ijcci.2022.100480.
[51] S.A. Ishak, U.A. Hasran, R. Din, Media education through digital games: a review on design and factors influencing learning performance, Educ. Sci. 13 (2) (2023) 102.
[52] A. Darwesh, Concepts of serious game in education, International Journal Of Engineering And Computer Science 4 (12) (2016) 15229–15232.
[53] F.G. Silva, Practical methodology for the design of educational serious games, Information 11 (1) (2019) 14.
[54] G. Kalmpourtzis, Educational Game Design Fundamentals: A Journey to Creating Intrinsically Motivating Learning Experiences, CRC Press, 2018.
[55] T. Kucher, Principles and best practices of designing digital game-based learning environments, International Journal of Technology in Education and Science 5 (2) (2021) 213–223.
[56] M. Moradi, K. Aliabadi, M.R. Nili AhmadAbadi, S. Pourroostaei Ardakani, Y. Mahdavi Nasab, Investigating the components of educational game design based on explorer player style: a systematic literature review, Interdisciplinary Journal of Virtual Learning in Medical Sciences 11 (3) (2020) 139–152.
[57] M.T. Cheng, Y.W. Lin, H.C. She, P.C. Kuo, Is immersion of any value? Whether, and to what extent, game immersion experience during serious gaming affects science learning, Br. J. Educ. Technol. 48 (2) (2017) 246–263.
[58] T.H. Laine, R.S.N. Lindberg, Designing engaging games for education: a systematic literature review on game motivators and design principles, IEEE Trans Learn Technol 13 (4) (2020) 804–821, https://doi.org/10.1109/TLT.2020.3018503.
[59] A. Asadzadeh, H. Shahrokhi, B. Shalchi, Z. Khamnian, P. Rezaei-Hachesu, Digital games and virtual reality applications in child abuse: a scoping review and conceptual framework, PLoS One 17 (11) (2022) e0276985, https://doi.org/10.1371/journal.pone.0276985.
[60] W. Mestadi, K. Nafil, R. Touahni, R. Messoussi, An assessment of serious games technology: toward an architecture for serious games design, Int J Comput Games Technol 2018 (2018).

[61] T.E. Coleman, A.G. Money, Student-centred digital game–based learning: a conceptual framework and survey of the state of the art, High Educ. 79 (3) (2020) 415–457, https://doi.org/10.1007/s10734-019-00417-0.
[62] C.S. González-González, P.A. Toledo-Delgado, V. Muñoz-Cruz, J. Arnedo-Moreno, Gender and age differences in preferences on game elements and platforms, Sensors 22 (9) (2022), https://doi.org/10.3390/s22093567.
[63] B. Manero, J. Torrente, C. Fernández-Vara, B. Fernández-Manjón, Investigating the impact of gaming habits, gender, and age on the effectiveness of an educational video game: an exploratory study, IEEE Trans Learn Technol 10 (2) (2017) 236–246, https://doi.org/10.1109/TLT.2016.2572702.