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Assessing Learning Outcomes Through Digital Game-Playing: A Systematic Literature Review

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Abstract. This paper aims to present a systematic literature review on empirical digital games (DG) studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was followed as a standard systematic literature review methodology. Twenty-five research papers were included in this review to determine the attributes of DGs that differently influenced learners' cognition, attitude and behaviour. It shows also how researchers of the included studies measured participants' progress whether during or after playing educational games. Based on the categories established and the analysis, the findings suggest that some features of games have affected diverse learning outcomes. There are also different ways of assessing the players' learning progress while playing a game which can be summarised in three methods: by using the feedback system in the game, analysing players' log file data, or applying external pre-tests and post-tests. This systematic review offers a helpful guideline for designing an effective educational game by considering games' attributes with different learning subjects and outcomes. Furthermore, it extends the guidance by providing a general list of how educators have assessed students' progress after playing an educational game. Thus, combining game attributes to attain specific learning outcomes and assessment methods to measure players' progress is a specific purpose of this paper. Recommendations for future research and for practice are provided as well as the paper's limitations.

Keywords: assessing learning progress; learning outcomes; digital game attributes; playing games; effective educational game

1. Introduction

In today's rapidly evolving educational landscape, there is an increase in the impact of sophisticated technologies and digital media on human psychological well-being and cognitive performance. These impacts are influenced by factors such as screen time duration and the specific activities individuals participate in within the digital environment (Korte, 2022). These digital media also cause

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"mind alterations or cognitive changes" of the younger generation (Prensky, 2001, p. 39). These changes have led to a variety of new preferences and needs in learning. The human brain does not change physically; however, after age three the brain changes based on received stimulation from the outside. Therefore, children's brains are able to adapt to high-speed presentations and thrive on them (Prensky, 2001). With continuous exposure and playing DGs, this game generation has had far more experience in processing information at faster than normal speeds. As students' cognitive styles evolve, educators are required to embrace novel tools that suit students' wish for twitch speed, graphics, and active learning (Whitton, 2014). One of the novel tools providing all those features is a DG. The use of games in education has become a transformative and captivating approach to learning. Games have evolved from being mere sources of entertainment to powerful tools for engaging students, fostering critical thinking and enhancing the educational experience. The integration of games in education has a profound impact on students' motivation, education and inspiration, making education more enjoyable and equipping students with the skills and knowledge needed to thrive in the 21st century. In addition, DGs as interventions revealed a medium effect on improving overall learning compared to traditional instruction methods (Barz et al., 2023). According to the current digital stream, the growing of the scientific publications on educational DG is a direct consequence of their widespread adoption and increasing significance during the technological advancements (Yeşiltaş & Cevher, 2022). For example, using DGs was found on the rise in higher education (Udeozor et al., 2023).

Additionally, 30% of teachers have been using DGs weekly inside the classroom to teach their students. In addition, 90% of these teachers have felt moderately to very comfortable with integrating games inside the classroom (Fishman et al., 2015). This refers to a new teaching approach that works properly with the "mind alterations or cognitive changes" of students. Varied types of games with different learning styles and for different subjects have been utilised for teaching as well as for assessment.

On the other hand, emphasizing learning outcomes has several advantages in terms of benefits for the course designer, quality assurance and learners (Adam, 2006). Thus, given the current popularity of DGs in the research field as well as the significance of the course's learning outcomes, the balance between gameplay and learning should be achieved in every DG intervention (Barz et al., 2023). Also, educational game designers must ensure that the learning content is effectively integrated without overshadowing the engaging game mechanics (Klisch et al., 2011). To achieve that, incorporating effective game features based on the types of outcomes would be encourage learning and foster a positive educational experience for students. Therefore, this systematic literature review aims to find the significant features or better integration of educational games that have influenced learners' cognition, attitudes and behaviour (from third grade to undergraduate students). In addition, this paper seeks to reveal how previous studies measured these different outcomes while playing DGs.

2. Assessing Learners Through Digital Game-Playing

Based on a meta-analysis, it was found that educational games have a moderate impact on enhancing overall learning, with a particular emphasis on cognitive learning outcomes. These findings were supported by the majority of the examined studies (Barz et al., 2023). In addition, DGs make students more engaged in learning activities when these games provide goals and challenges (Mislevy et al., 2012). Engagement is an important element in learning as well as in assessment. Simultaneously, players, who are learners, are immersed in the gaming world and in the learning activity. This immersive and engaging situation encourages players to practise previously learned skills and knowledge. While playing games, students naturally generate rich sequences of actions while performing complex tasks, relying upon certain skills which are also assessed such as critical thinking or problem-solving (Shute et al., 2008).

Furthermore, games foster intrinsic motivation, thereby enhancing the enjoyment of learning instead of relying solely on achieving high grades (Alessi & Trollip, 2001; Horton, 2012). Researchers propose that students who exhibit higher levels of motivation tend to have their abilities more accurately represented in their assessment outcomes (Mislevy et al., 2012). That is, a well-designed game-based assessment (GBA) immerses students in a motivated and engaging environment where stealth assessment comes in (Shute & Ke, 2012).

Some GBA research intends to design games for assessing users' academic achievement. Regarding formative assessment in general, it means students are assessed on an ongoing basis over the course instead of measuring the students' skills and knowledge acquisition at a single point in time (Kubiszyn & Borich, 2010). By applying formative assessment across multiple points of time (weekly or monthly), students who are not responsive to instruction can be quickly identified. It can also indicate students who have made sufficient progress. In GBA, formative assessment is important to measure students' learning while playing a game rather than after completing the whole game (Belland, 2012). Thus, teachers can quickly adjust the level of course/intervention instruction provided to students (Kubiszyn & Borich, 2010). Furthermore, providing immediate feedback and frequent assessment is designed to "inform students of the adequacy of their learning process and what can be done to improve learning" (Belland, 2012, p. 30). Thus, assessing through playing a game requires students to perform actions then receive immediate feedback based on the quality of their actions (Belland, 2012).

3. Previous Research

This paper investigates the impact of DGs on different learning outcomes to explore the key game attributes that contribute to the learner's educational progress. An exploration of relevant studies and research papers was conducted, revealing two main themes: the theoretical framework of games and assessment, and the relationship between DGs within specific subjects and learning outcomes. The following section provides a concise overview of these two themes.

3.1 Theoretical Framework of Games and Assessment

Some studies have investigated the theoretical and practical framework for developing GBAs. One of these studies provided the Assessment Data Aggregator for Game Environment (ADAGE) model as a framework for GBA (Owen et al., 2014). This model relies on the click-stream data that is collected while users play the game. It provides a "standardised game telemetry framework with a rich, method-agnostic data yield, efficient enough to have scalability, and flexible enough to use across games" (Owen et al., 2014, p. 1). The researchers found that (ADAGE) model helped to demonstrate a way to use click-stream data as learning evidence. To make this model practical, Halverson and Owen (2014) have implemented it. They examined the "Progenitor X1" game with middle school students following a science course. They found a 19.5% increase in student gains, which points to overall gameplay progress and gameplay successes. However, this model requires rich and method-agnostic data that is not available in several software for creating games. Moreover, in this GBA model, educators and designers must have a system that enables them to capture rich user data. Another proposal for GBA framework, an evidence-centred design (ECD) by Mislevy, Steinberg, and Almond (2003). They claim that a design for valid and high-quality assessment can yield real-time estimates of students' competency levels over a range of knowledge and skills. This ECD-based assessment generates the term "stealth assessment" indicating an assessment that is woven directly and invisibly into the fabric of the learning environment (Shute & Ke, 2012, p. 52). In sum, studies with a "GBA" title with theoretical and practical framework were limited.

3.2 Outcome-focused Design

The primary benefit of learning outcomes is the enhanced clarity and precision they provide in the process of curriculum development (Adam, 2006). Based on the reviewed papers, learning outcomes are classified into three types: cognitive outcomes, affective outcomes, game performance and behaviour change. Curriculum developers, game designers, researchers or educators must sketch learning outcomes that involve different tasks – cognitive tasks, communication and metacognition. These outcomes must be explicitly selected or rejected as part of game specification (Baker & Delacruz, 2008). Accordingly, attributes of various game influenced specific learning outcomes. In addition, several methods have been reported to measure learners' progress with different outcomes. By aligning learning goals with the outcomes of a game, it becomes possible to assess players' performance according to various dimensions. These dimensions involve the complexity, the richness of content, the understanding of interrelationships, and the ability to perform the desired and final tasks (Baker & Delacruz, 2008). Thus, employing game attributes that positively affect students' cognition, affective outcomes and performance would naturally extract the students' knowledge and skills. Furthermore, assessing the intended knowledge and skills through playing games would reflect students' abilities without stress, confusion or cognitive load.

4. Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was followed as a standard systematic literature review methodology.

For more details, a PRISMA 2009 flow diagram is provided in Figure 1 (Moher et al., 2009).

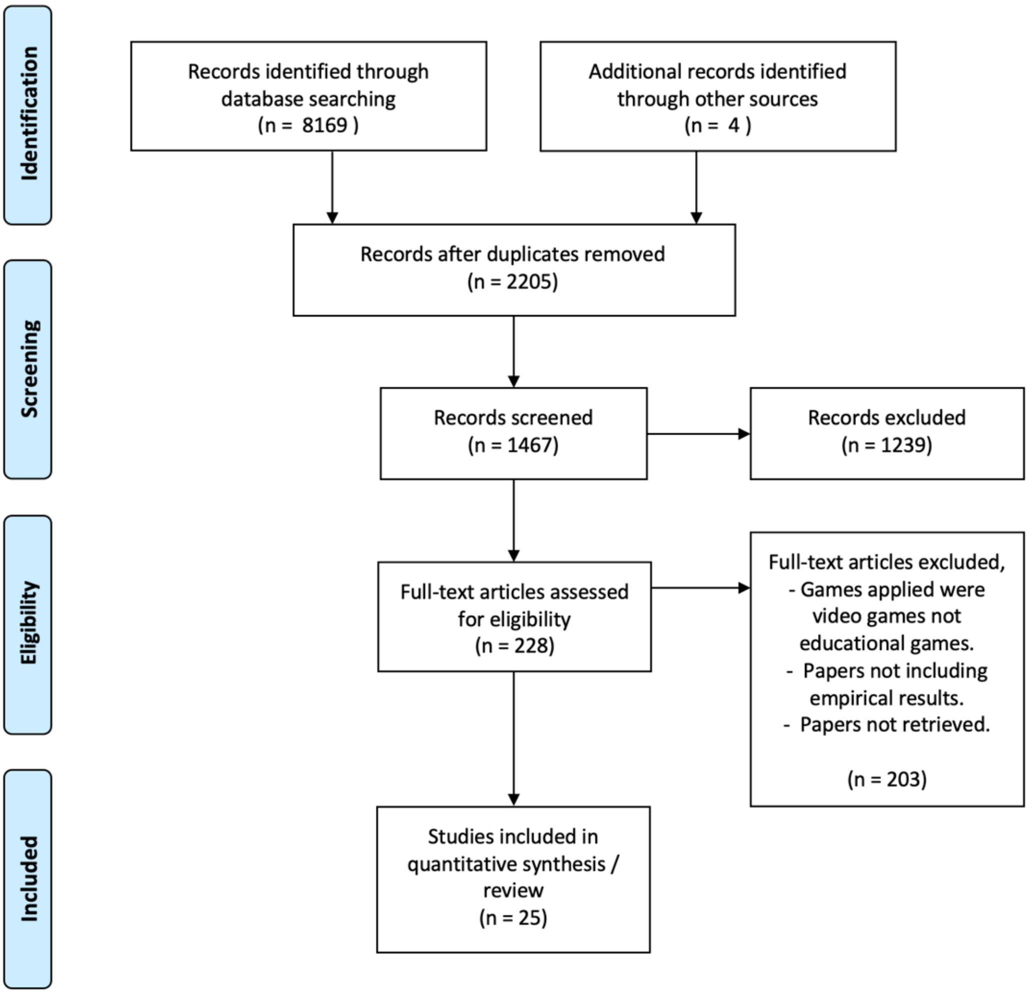

Figure 1: The PRISMA flow of the current review (Moher et al., 2009)

First, research questions were compiled and used as fixed set of queries on a pre-identified bibliographical database. Then, a set of inclusion and exclusion criteria were defined. After that, a full paper review and coding process of the selected research papers were undertaken. Last, a synthesis and analysis of the coding outcomes were completed. Research papers from 2000 to 2020 restrictions were set.

5. Research Questions

This systematic literature review aims to answer the following questions:

1. What are the DG attributes that influence learners' cognition?
2. How did researchers measure cognitive progress in learners?
3. What are the DG attributes that influence learners' affective outcomes?
4. How did researchers measure progress in learners' affective outcomes?
5. What are the DG attributes that influence learners' behaviour?
6. How did researchers measure progress in learners' behaviour?

6. Databases and Search Terms

Studies used games in the classroom with applied assessments to measure students' learning or monitor students' progress are included to answer this paper's questions. The selected studies had game features that influenced students' cognition, affective outcomes or playing performance and behaviour. Collecting a set of significant features of games that influence students' progress would help game designers and educators to create successful games for learning and assessment (Shute & Ke, 2012).

Regarding this paper's goals, different attributes of DG or GBA that differently influence learners' cognition, attitude and behaviour as well as methods of measuring participants' progression after playing a game were summarised. Databases included Academic Research Premier, the Web of Science database, EdITLiB database, Google Scholar, and some studies' references. Regarding the search terms, GBA or games for assessing learning were chosen. Thirteen studies in Academic Research Premier, 89 studies in Web of Science, 1 577 studies in EdITLiB database, and 6 490 results in Google scholar were found at the start of the search. After browsing the titles, abstracts, and participants' ages for the studies, the number of the articles dropped. For example, only 4 studies from Academic Research Premier database and six studies from Web of Science database were selected.

7. Inclusion and Exclusion Criteria

After gathering the initial collection, the duplicated papers were excluded (2 205 studies). Then, a first brief review of all papers was made and then compared against the inclusion and exclusion criteria (Table 1). After this stage, studies were classified as included or excluded. The included papers met all the following conditions. These conditions were applied sequentially, so that if a paper did not match a certain criterion, it was excluded immediately from the collection.

Table 1: Inclusion and exclusion criteria for this review paper

Inclusion Criteria	Exclusion Criteria
• School ages 5th – undergraduate students. • Digital educational games. • Individual playing. • Game has been designed to assess students' knowledge, achievement or progress in literature; because of the small number of studies in GBA, I extend the subject area to include any subject matter (STEM, Social Studies and Business). • Academic journals, periodicals and conference papers. • As outcomes, I include students' achievement, performance, motivation and engagement.	• Preschool- second grades. • Virtual worlds. • Video games. • Online collaborative learning. • Games in health and medical areas. • Testing anxiety as an outcome. • Dissertation papers because most of them are not available as a full text.

• The study had to report process measures or affective outcomes if the study had an experimental design. • Time span of research from 2000–2020.	

8. Quality of the Studies

The features used for coding each study consisted of authors; title; APA citation; research questions; grade level; curriculum subject; research design (randomized experimental and control-comparison, quasi-experimental and control-comparison, non-equivalent control group, one-group pre and post, one-group post-test, qualitative-action research, qualitative-case study, qualitative-ethnography, other); type of outcomes (achievement-knowledge test, achievement-understanding or problem solving, achievement, perception – perceived learning, attitudes, learning behavior); how they measure the outcomes (standardised test; researcher-made test; teacher-made tests; journals; surveys; interviews; observations; focus group; other); technology; type of games (action, adventure, fighting, puzzle, role playing, simulations, sports, and strategy game); pedagogy (lecture, individual inquiry-problem solving, individual practice, collaborative inquiry-problem solving, mix); teacher role; N total; pre-test mean and Standard Deviation (SD) for experimental group; pre-test mean and SD for control group; post-test mean and SD for experimental group; post-test mean and SD for control group; key findings; strengths; limitations; other moderating factors and connecting this study to GBA design.

Coding accuracy. To ensure coding accuracy, each study was coded twice, once in a Word coding book and the second time on an Excel coding sheet. Also, each study, especially the instrument, procedure and results sections, were read more than twice.

Quality of included studies. To demonstrate a study's quality, quality indicators mentioned in a study by Lauer et al. (2006) were followed by the author to rate quantitative studies. These quality indicators helped to classify the included studies as being low or medium quality (Table 2).

Table 2: Quality indicators for rating quantitative studies (adopted from Lauer et al., 2006)

Quality Indicators	Description (Low / Medium)
Construct Validity	• The description of the intervention (the game) is incomplete / is adequate. • Treatment fidelity is discussed, but there is no report of its assessment / none is reported (Treatment fidelity measures – strategies that monitor and enhance the accuracy and consistency of an intervention to ensure it is implemented as planned and that each component is delivered in a comparable manner to all study participants over time). • There is evidence of face validity of the outcome measure but not for the construct it represents / There is evidence for the alignment

	of the outcome measure with the intervention and for construct validity of the outcome measure.
Internal Validity	• The steps taken to make student groups comparable may have been inadequate / adequate. • Although alternative explanations for results are not readily apparent, some remain plausible / alternative explanations for results are ruled out.
External Validity	• Only some of the important characteristics of the participants, settings, and outcomes are represented in sample / most of the important characteristics are represented. • The intervention (game) was tested for effectiveness with only a few important subgroups of participants / with most but not all-important subgroups of participants.
Statistical Validity	• Effect sizes can be calculated for only some outcome measures due to insufficient reporting / for most but all outcome measures.

The final collection of papers consists of 25 studies, and all were rated as medium quality. Most of them were lacking a sufficient description of the game as well as the experiment settings. Furthermore, the effect sizes of the outcome were insufficiently reported.

9. Overview of Included Studies

To design e-learning – which includes DG – for students, instructional designers or educators must be aware of their learners and subjects to determine the best learning experience to teach them (Horton, 2012). They must also know the students' abilities and attitudes, so they can build a learning environment that balances the learning objectives and learners' needs. Thus, focusing on the desired outcomes would be a way to examine the consistency between the learning environment and learners' needs. These outcomes should be explicitly chosen or rejected (Baker & Delacruz, 2008). These prominent outcomes exploit content that the game is supposed to teach such as content facts, procedural knowledge or step-by-step tasks. Additionally, a game can promote auxiliary knowledge that is not the game's primary goal (Baker & Delacruz, 2008).

Types of outcomes were classified and shown as key features of this literature review. Depending upon these outcomes, game's attributes for each study have been summarised. In total, 25 studies were included in this systematic literature review. All the studies, except one which was mixed method, used a quantitative research method (Table 3).

Table 3: Overview table of all twenty-five studies included in this paper

	Author (year)	N of Participants	Grade Level	Subject	Type of Game	Type of Outcomes
1	Klassen & Willoughby (2003)	27	Undergraduate Students	Busines s	Strategy Games	Knowledge & Enjoying the Game (COs & AOs)
2	Huang & Cappel (2005)	179	Undergraduate Students	Busines s	Puzzle Game	Satisfaction Levels with the Game, Perceived

	Author (year)	N of Participants	Grade Level	Subject	Type of Game	Type of Outcomes
						Benefits from the Game (AOs)
3	Ke (2008)	15	Late Elementary School	Math	Puzzle Game	Cognitively and Affectively Interact with the Game (COs & AOs)
4	Papastergiou (2008)	88	High School	Computer Science	Action Game	Knowledge & Student Engagement (COs & AOs)
5	Gao, Yang, & Chen (2009)	44	High School	Social Studies	Simulation Game	Academic Achievement & Problem-Solving (COs)
6	Lee & Chen (2009)	78	High School	Math	Puzzle Game	Problem-Solving Skill, & Mathematics Attitude (COs & AOs)
7	Ben-Zadok, Leiba, & Nachmias (2011)	7434	Late Elementary School	Science	Puzzle Game	Learning Behaviours in Each Activity & Motivation to Learn (BOs & AOs)
8	Klisch, Miller, Wang & Epstein (2011)	444	Middle School	Science	Role Playing Game	Knowledge, Attitude, Satisfaction with the Game (COs & AOs)
9	Spires, Rowe, Mott, & Lester (2011)	137	Middle School	Science	Role Playing Game	Problem-Solving Skill (COs)
10	Schrader & Bastiaens (2012)	135	Middle School	Science	Role Playing Game	Virtual Presence, Cognitive Load and Learning Retention, Comprehension and Near and Far Transfer (COs & AOs)
11	Guillén-Nieto & Aleson-Carbonell (2012)	50	Undergraduate Students	Business	Simulation Game	Student Engagement & Knowledge (COs & AOs)

	Author (year)	N of Participants	Grade Level	Subject	Type of Game	Type of Outcomes
12	Erhel & Jamet (2013)	90	Undergraduate Students	Science	Puzzle Game	Knowledge, Recall, Learners' Motivation (COs & AOs)
13	O'Neil, Chung, Kerr, Vendlinski, Buschang, & Mayer (2014)	114	Middle School	Math	Puzzle Game	Knowledge, Learning Process (COs)
14	Miller, Baker, & Rossi (2014)	462	Late Elementary School	Math	Puzzle Game	Knowledge, Problem-Solving, & Knowledge Fluency (COs)
15	Halverson & Owen (2014)	110	Middle School	Science	Puzzle Game	student gains by Players' Efficiency Ratio and Performance (COs)
16	Martin & Shen (2014)	172	Undergraduate Students	Science	Puzzle Game	Knowledge (or Rote Memorisation) (COs)
17	Hou & Li (2014)	67	University Students	Compu ter Science	Role Playing Game	Knowledge, Flow and Acceptance of the Game (COs & AOs)
18	Tsai, Tsai, & Lin (2015)	109	High School	Science	Puzzle Game	Knowledge, Playing Ability, Enjoyment, & Involvement Perceptions (COs & AOs & BOs)
19	Cheon, Chung, & Lee (2015)	298	Undergraduate Students	Social Studies	Action Game	Perceived Enjoyment, Satisfaction, Game Expertise, Recall of the Content & Change in Behaviour (COs & AOs & BOs)
20	Chang, Evans, Kim, Norton &Samur (2015)	306	Middle School	Math	Role Playing Game	Math Proficiency, Math Engagement (COs & AOs)

	Author (year)	N of Participants	Grade Level	Subject	Type of Game	Type of Outcomes
21	Holmes (2015)	369	Late Elementary, Middle, High School	Science	Strategy Game & Simulation Game	Students' Interest, Students' Attitude, Knowledge (COs & AOs)
22	Homer, Plass, Ober, & Ali (2018)	82	High School	Cogniti ve Skills/ Brain Trainin g	Action Game	(DCCS) Task (a measure of shifting) and the Flanker Task (a measure of inhibition), & Students' Performance in the Game (COs & BOs)
23	Fokides (2018)	201	Late Elementary School	Math	Puzzle Game	Knowledge, Interest of Students & Motivation, & Students' Experiences in the Games Groups (COs & AOs)
24	Chen, Yang, Huang & Fu (2019)	204	Undergraduate Students	Science	Puzzle Game	Learners' Motivation, Attention, & Learning Outcomes (COs & AOs)
25	Feng & Yamada (2019)	185	Late Elementary, Middle, High School	History	Puzzle Game	Knowledge, Behaviour Patterns, Players' Characteristic s (COs & BOs)

Key: (COs = Cognitive Outcomes, AOs = Affective Outcomes, & BOs = Behaviour Outcomes)

10. Results

Following a comprehensive review of the 25 selected studies, three prominent themes emerged: the participants involved in the studies, the types of games used in the classroom setting, and the potential of playing games as an assessment tool. Each of these themes is be explored. Furthermore, each theme is examined in relation to various learning outcomes, including cognitive outcomes, affective outcomes, and learners' behaviour.

First Theme: Games in Different Curriculum Subjects and Student Grades

- **Late elementary to middle school students:**

Science, Mathematics and History games were examined with students of this age. Two studies included samples of both secondary school students and late elementary students, who were in third, fourth and fifth grade. Other studies recruited students from elementary school, secondary school and high school (Table 4).

Table 4: Overview for curriculum subjects among students in different grades

Curriculum Subject	N of Studies	School Grades
Science	10	Late Elementary, Middle School, High School and Undergraduate Students.
Math	6	Late Elementary, Middle and High School.
Business	3	Undergraduate Students.
Computer Science	2	High School, and Undergraduate Students.
Social Studies	2	High School, and Undergraduate Students.
History	1	Late Elementary, Middle and High School.
Cognitive Skills/Brain Training	1	High School.
Total	**25**	

- **High school students:**

For this grade, DG studies were conducted in Science, Mathematics, Computer Science, Social Studies, History, and Cognitive Skills (Table 4).

- **Undergraduate students:**

Science, Business topics, Computer Science and Social Studies were the educational game curriculum subjects and skills for these students (Table 4).

Second Theme: Types of Games in Classrooms

DGs are categorised into eight genres, which often overlap. They are action, adventure, fighting, puzzle, role playing, simulations, sports and strategy games (Prensky, 2001). Based on these categories, games used in the reviewed studies were classified and it was found that they involved these following five genres of games:

1. Action games – "side scroller" games or maze games.
2. Puzzle games – problems to be solved, typically visual, stripped of all story pretence.
3. Role playing games (RPGs) – quests usually to rescue someone or something, playing a character who has a "type" (human, elf, wizard, etc) and a set of individual characteristics that the player assigns it; it involves player equipment and experience via action and fighting (e.g., spells are a big deal).
4. Strategy games – player is overseeing something big (e.g., business deal).
5. Simulation games – about building worlds like SimCity.

Third Theme: Playing Games as an Assessment Tool

- **While playing the game:**

In one study, researchers designed GBA that gathers evidence of learning progress by passing the game's eight levels. Successfully passing the sequence of game levels to reach the last level (Boss-level) indicates improvement in student's knowledge and skills that allow them to complete the game (Halverson & Owen, 2014). Another way to monitor students' progress was providing DG as a formative assessment supported by a feedback system.

- **Analysing students' click-stream data:**

Instead of looking at player scores, other researchers gather and record the full interaction of students during playing the game by the "log files". They compute variables in the log file (e.g., where the student answered all questions before leaving the game, receiving positive feedback before the student left the unit, and time spent between two questions). By comparing these variables, results revealed the number of students who performed each activity, percentage of students who performed each activity until they were successful, the average response time to questions in each activity (Ben-Zadok et al., 2011). Another way was computing the player's "efficient ratio" to translate the data to meaningful patterns, where Efficiency Ratio = (number of successes) / (number of tries) (Halverson & Owen, 2014).

- **External tests assess students' progress:**

In many studies, researchers ask participants to play an educational game in between a pre-test and post-test. This method allows researchers to examine the game's impact on a player's knowledge and skills. Conducting comparisons between players' scores after and before the game would help to detect advantages and disadvantages of that game for learning. Researcher-made tests or questionnaires were other ways to reveal a game's impact on learning and motivation.

After presenting an overview of the 25 studies included in this review as well as the three themes of these studies, the next section will present the three types of learning outcomes. They are classified as cognitive outcomes, affective outcomes and game performance or behaviour change.

11. Answering the Research Questions (RQ):

Regarding the Cognitive Learning Outcomes:

Overall, 23 out of 25 studies (92% of the selected articles) focused on the cognitive results as desired outcomes (Table 5).

Table 5: Overview table for games genres in the included studies according to the types of outcomes.

Types of games / Types of outcomes	Action game	Puzzle game	Role playing game	Simulation	Strategy game	Total number of studies
Total number of each type of game among 25 studies	3	12	5	3	2	25
Cognitive outcomes	3	11	4	3	2	
Affective outcomes	2	8	4	2	2	
Learner's behaviour/ Game performance	2	3				

These cognitive outcomes include potential improvement in declarative knowledge; cognitive load; students' ability to retain information; comprehension and near transfer; students' prior knowledge and its impact on receiving game benefits; students' progress or students' achievement; problem-solving skills; and executive function subskills. These outcomes were evident in all five types of games (action, puzzle, role playing, simulation and strategy games). They also appeared in a range of curriculum subjects such as Science, Math, Business, Computer Science and Social Studies. Examining these cognitive outcomes covered different ages, starting with students in fifth grade right up to undergraduate students.

(RQ-1) What are the digital game attributes that differently influence learners' cognition?

Regarding the cognitive outcomes and playing educational DG in the classroom, many valuable attributes of games emerged. One study showed that educational games are better when providing immediate elaborated feedback (IEF). Adding feedback in DG enhances memorisation and the effectiveness of knowledge acquisition (Erhel & Jamet, 2013; Tsai, Tsai & Lin, 2015). Furthermore, when a game incorporates elements of entertainment, instructions and knowledge of correct response feedback, it leads to improve performance in comprehension (Erhel & Jamet, 2013). In contrast, summative feedback (''correct" or ''wrong") rather than informative elaborated feedback leads to poor participant reflection in terms of the essential learning cycle such as performance analysis, new knowledge generation and evaluation (Ke, 2008). The different gaming modes (single-player online game and multiple-player online game) did not affect the effectiveness of knowledge acquisition (Tsai et al., 2015). Therefore, embedding immediate feedback is more beneficial in terms of knowledge acquisition than gaming modes.

To organise the instructional sequence in a game, theory items or conceptual instructions are better given at the beginning of the course of instruction, especially on a new topic. While speed games are designed to evaluate students' problem-solving abilities and knowledge fluency, these games should be introduced later in the learning process to refine and solidify the knowledge that students have already begun to acquire (Miller et al., 2014). Regarding mathematical symbols and their underlying concepts, a self-explanatory prompt after completing each level in a game helps students to see the relationship between the abstract elements in mathematics and the concrete elements in the game. The self-explanation prompt should be moderate, neither too simple, nor too complex (O'Neil et al., 2014). Another study investigated two forms of prompts: specific prompts (directed prompts) and general prompts, in non-routine mathematical tasks. For a non-routine difficult task, students who received specific/directed prompts outperformed those who received general prompts in math problem-solving performance. Since specific prompts could present more detailed cues, these types of prompts directed students' attention to important information that they might have neglected. The students presented intensive learning support to finish a difficult and non-routine mathematical task (Lee & Chen, 2009).

For declarative knowledge or rote memorisation, games with aesthetics – sounds and animations, meaningful choices and the competition features – had a relatively high impact (Martin & Shen, 2014; Papastergiou, 2008). The ideal balance between discovery elements and embedded supports in a game appears to play a crucial role in facilitating the cognitive process supported by the content. Thus, a game with intrinsic support (which gives simple hints) reported the highest scores in student retention, comprehension and near transfer. This intrinsic support also demonstrated the lowest mean of students' cognitive load during game-playing more than a game with extrinsic support (which gives a visible button with a hyperlink to the textbook). Various tools embedded within the game – e.g., speaking with other characters; exploring the island; reading books and posters; or conducting tests in the laboratory – support students' cognitive load (Spires et al., 2011). Meanwhile, shallow cognitive processes may occur when students are not explicitly encouraged to learn. Thus, students have better comprehension when a game presents learning instruction (Erhel & Jamet, 2013).

DGs offering immersive explorations and conveying expectations regarding the subject content are likely to be encountered in an enjoyable and engaging manner. It aids in fostering a deeper comprehension among students (Huang, & Cappel, 2005). Furthermore, games are more effective in solving problems when they provide practice. These games allow learners to re-examine their solutions and methods (Gao, Yang & Chen, 2009). Playing DG during the class is an opportunity to construct and practise strategies and skills, such as hands-on activities (Klassen & Willoughby, 2003). These embedded learning tasks and practices should be integral to the game story with challenging activities (Ke, 2008). Additionally, a good game presents the content model to a player through compelling in-game moves and strategies. Thus, completing a game requires player to solve a series of sequenced learning objectives as sequential missions. For example, the first mission/task teaches players a desired piece of knowledge or skill to gain the first learning objectives. After acquiring that, players can pass the level and move to the next one. The final level would require all skills and knowledge that players have learned by completing the previous levels/missions. This way the game-flow and the content model are connected (Halverson & Owen, 2014).

(RQ-2) How did researchers measure cognitive progress in learners?
Most studies measured players' knowledge acquisition, academic achievement or problem-solving skills by comparing the average between pre-test and post-test scores. Players or students were asked to take a test before exposure to the intervention, which was a digital game-based learning or game-based assessment, in addition to another test after playing the game.

Another way to measure cognitive achievement in the selected studies was analysis of players' click-stream data. Halverson and Owen (2014) used telemetry data, calculating players' efficiency ratio, and the change in performance on the pre-post content tests as evidence of players' learning progress. Telemetry data represents a "generic information gathering mechanism to transform key-moment click-stream data into play profiles" (p. 2). Then, they developed an efficiency ratio that measured the number of successful task completions by a player over the number of times the task was tried. Other researchers applied only a post-test assessment to examine players' progression after playing a game.

Another way to monitor the learning process was recording the players' maximum level reached, mean number of deaths per level, and mean number of resets per level (O'Neil et al., 2014), or by using the Bayesian Knowledge Tracing (BKT) method to track student development of specific cognitive skills across all three activities (conceptual instruction, problem-solving items and fluency-building games) (Miller et al., 2014). This involves "a running assessment of the probability that a student currently knows each skill, continually updating the estimate based on student behaviour" (p. 4).

Regarding the Affective Learning Outcomes:
Regarding affective learning outcomes, 17 studies investigated DGs with these types of outcomes (68% of the selected articles). Affective outcomes consist of student motivation, student engagement and enjoyment, game flow and acceptance, student satisfaction, virtual presence and student attitude and interest toward the subject matter. Like the cognitive progress, affective outcomes were shown in all five types of games. Science, Math, Business, Computer Science and Social Studies' games were examined under this outcomes category. Additionally, students from first grade right up to the highest considered grade, which was undergraduate students, were included in some studies related to affective outcomes.

(RQ -3) What are the digital game attributes that differently influence learners' affective outcomes?
In terms of affective outcomes after playing educational games in the classroom, many game attributes emerged. Different gaming modes (single-player online games and multiple-player online games) and different feedback types (IEF, and no IEF) did not significantly affect learner enjoyment (Tsai et al., 2015). In addition, no significant difference was found between given undergraduate students educational and entertaining instructions in terms of motivation and intrinsic motivation (Erhel & Jamet, 2013). However, Papastergiou (2008) noticed that high school students who played on a computer science game seemed enthusiastic when they were told that they would use a game for educational purposes. They manifested high levels of engagement in their effort to maintain their chance to be alive in the game. These different results might be due to the different sample grades (undergraduate students vs. high school students). For first, fourth and sixth grader, the increased interest and motivation while playing the math games were noted (Fokides, 2018). In addition, fourth and fifth-grade students who received math instruction combined with entertainment and feedback on correct responses demonstrated improved skills in managing their fear of failure, in contrast to those who received learning-focused instructions in the game. These students may have redirected their focus from avoiding failure to achieving better results in comprehension tests, which could be attributed to changes in working memory (Erhel & Jamet, 2013). In addition, games can encourage students to reflect learning while playing by providing informative feedback which includes debriefing and scaffolding features (Ke, 2008).

Regarding the feedback provided in a game, debriefing and scaffolding features as informative feedback encourage learning. This informative feedback can also be used as a modelling tool to visualise and abstract relevant information and see some of the basic variables and examples from a whole complex experience (Ke, 2008).

Another study showed three types of providing support in the game: game without support (G), game with extrinsic support (G_ES), and game with intrinsic support (G_IS) (Schrader & Bastiaens, 2012). G group was learners solving the required tasks without any support. While G_ES group had the learning concepts presented in a permanently visible button with a hyperlink to the textbook, the G_IS group had a pedagogical agent giving simple hints to encourage learners to keep trying if they have made an error. The results demonstrated that games without support involve an increased sense of virtual presence – the feeling of being involved in the gaming environment. This feeling of virtual presence was also higher in a group exposed to a game with intrinsic support (giving simple hints) than in the group exposed to a game with extrinsic support (giving a visible button with a hyperlink to the textbook).

For non-routine mathematical tasks, they are considered as effective tasks in engaging students' intellect as well as capturing their interest and curiosity (Lee & Chen, 2009). Additionally, the easier a player found the game mechanics, the more likely it was that student learned from it. Thus, the more students learned from a game, the more their attitudes toward a topic changed (Klisch et al., 2011). Players' enjoyment perception positively affected usefulness perception. This implies that players/learners will perceive a game as a valuable learning tool if that game is fun (Cheon et al., 2015). Besides the acceptance of the game and flow experiences during playing the game are prerequisites for effective game-based learning (Hou & Li, 2014). These satisfaction levels with the DG did not vary significantly across any of the demographic factors considered between undergraduate students in relation to a business puzzle game (Huang, & Cappel, 2005). On the other hand, students who possess low-prior knowledge are more engaged and satisfied with the game (Chang et al., 2015; Guillén-Nieto & Aleson-Carbonell, 2012). Beyond this, robust positive associations between students' evaluations of interest, attitude, and their academic performance was observed in science (Holmes, 2015). However, the potential to boost learning motivation through DGs is not guaranteed, as the outcomes can hinge on various variables, including the inherent enjoyment of the educational game and the audience's inclination toward learning through gameplay (Chen et al., 2019).

Regarding learning environment constructure, the most significant activities should be located at the beginning of the unit, when students still have the willingness and motivation to learn. To illustrate, asking students to play an educational game after practising a drill activity and before a self-test leads students to skip the game and move to a more serious tool (the self-test). Here students might think that playing a game is not a learning tool (Ben-Zadok et al., 2011). However, games can be effective even if they are simple drill games (Ben-Zadok et al., 2011; Ke, 2008). To make a game more persuasive, DGs are better designed with non-threatening and indirect messages rather than direct and fear-based messages. In this way, the game provides a ''stealth'' prevention message. In terms of the user's response format in educational games, it should not involve only multiple-choice items that enable guessing and random clicking (Ke, 2008).

(RQ -4) How did researchers measure progress in learners' affective outcomes?
Based on the reviewed studies, researchers applied two methods to compare players' motivation, attitude or other affective outcomes. They used pre-test and post-test score comparison, or only an immediate post questionnaire following the end of playing to reflect players' affective outcomes.

Regarding Game Performance and Behaviour Change:
Only five studies out of twenty-five had examined the impact of DGs on students' playing performance. In other words, 20% of the selected articles investigated the influence of playing educational games on student's behaviour in real life, as well as their game performance and playing ability (Table 5). Puzzle games, alongside action games, dominate these studies' games among students in late elementary school (third to fifth grade), high school and undergraduate students. Science, Social Studies, Cognitive Skills or Brain Training, and History were the subjects to achieve these types of outcomes from playing DG.

(RQ-5) What are the digital game attributes that differently influence learners' behaviour?
Regarding the changes in-game performance as outcomes, four games attributes have been found. First, providing IEF messages enhanced the effectiveness of acquiring tic-tac-toe playing skill (Tsai et al., 2015). This type of feedback reinforces the understanding of that skill. Second, playing as a single-player or multiple-player in a game did not improve the ability to play the game. Third, as mentioned in relation to DG affective outcomes, players' satisfaction and enjoyment are significant for gaining desired outcomes. These feelings of satisfaction and pleasure in a serious game meant learners were more likely to intend to change behaviours (Cheon et al., 2015). Fourth, game designers should consider the timed tasks especially when the game comes before a quiz or test. When game time is limited, students prefer to skip it and move to the "real learning activities", so they moved from the game activity to the test/quiz. Around half of the students (57.43%) completed the game until they succeeded without skip playing (Ben-Zadok et al., 2011).

(RQ-6) How did researchers measure progress in learners' behaviour?
Three different methods were applied to measure the performance changes or learner's behaviours. First, pre-test and post-test questionnaires were used to assess any change in playing ability (Tsai et al., 2015). Second, a post survey was applied for students to answer questions about their behavioural intention after playing the game. A third method for measuring students' behaviour was using players' log files and statistically analysing them to explore the students' learning behaviours in each learning activity and their motivation to learn (Ben-Zadok et al., 2011; Feng & Yamada, 2019). Log files were also used to consider time played, levels completed and reaction time (Homer et al., 2018).

12. Findings Summary

This paper aimed first to assemble the attributes of DGs among twenty-five studies. These games' attributes influence learners' cognition, attitude and behaviour differently . Focusing upon the three outcome types, games' features were summarised. Illustrating the impact of specific game features on learning outcomes serves as a valuable reference for designing effective educational games. Second, this paper presents how researchers of the reviewed studies measured participants' progress. More details are presented below.

Game's attributes with cognitive outcomes. Each game's features affected varied learning outcomes. Many characteristics have been embedded in GBL and present significant progress in learners' comprehension and knowledge acquisition, for example by providing correct response feedback, adding hints and clues within a game, and encouraging students to learn from playing a game. Meanwhile, IEF enhances knowledge acquisition as well as reinforcing the understanding of gaining a playing skill. Other game features support cognitive process especially when moderate self-explanation prompts ask students to choose an explanation of their movement, or internal support appears while students play a game. Problem-solving skills also improve if a game is equipped with direct and detailed prompts especially in a difficult task. The ease and flow of a game are important regarding a student's acceptance of and satisfaction with a game, which in turn affect how much knowledge and skills are gained. Designing a game that presents conceptual knowledge first and then tests students' knowledge and skills by asking them to complete tasks also enhance students' problem-solving skills and knowledge fluency. Games with aesthetics and intrinsic support have positive influences on gaining declarative knowledge. Representing content in more detail and clarifying expectations and questions about the topics can enhance students' understanding. Meanwhile, these activities and practices should not interrupt the game flow; however, they should be integral to the game story. The greater students' acceptance of a game, and the level of ease of a game's mechanics, the more likely it is that they will learn from it (Klisch et al., 2011).

Game's attributes with effective outcomes. Offering a game in a classroom for educational purposes motivates high school students. Late elementary school students, who play a game with entertainment instructions accompanied by correct response feedback, achieve better than students who play a game with educational instruction. In contrast, entertainment instruction and educational instruction did not influence undergraduate student motivation differently. Thus, the type of instructions presented in a game should be considered depending on the age of the targeted audience. Also, students have the willingness to learn at the beginning of the course unit, so most significant activities might take place at the beginning to tap into the students' motivation. In addition, the ease of a game-playing facilitates learning from that game. Adding hints and helpful clues can increase students' feeling of being involved in the gaming environment. Once students have been involved in the learning environment, they would perceive a game as a valuable learning tool.

Game's attributes with learners' behaviour and game performance. Briefly, a game is effective and influences a learner's behaviours when it presents IEF that reinforces the understanding of that skill. Designing a game that fulfils players' satisfaction and pleasant feelings is challenging, but significant because learners who play a game with feelings of satisfaction are more likely to change their behaviours according to the game's messages. Additionally, in a game that has different activities in a static order (e.g., drill activity followed by game then test) designers should consider the time for completing each required task. However, certain player attributes may have had an impact on the cognitive skills associated with learning outcomes, they were not found to exert a direct influence on behavioural patterns (Feng & Yamada, 2019).

Ways of assessing learning progress through playing games. Regarding the ways of assessing players' learning progress through playing GBL, studies show three different ways. Those ways of assessing the players' learning progress can be recapped according to three applied methods. the first way was using the feedback system in the game. The feedback systems (e.g. points, scores, stars, or dashboards that provide an overview of progress and screen captures) can serve as a point of communication (Fishman et al., 2015). Other methods employed were pre-test and post-test score comparison, or only post questionnaires that reflected players' cognitive outcomes, affective outcomes or game-playing ability and behaviour changes as well. Other researchers used and analysed players' click-stream data. Click-stream data are used to examine learners' cognitive outcomes and performance changes as well. One study utilised the BKT method to track students' cognitive skills during game-playing activities. Another study statistically analysed players' log files to monitor their behaviours in each activity (drill practice, game-playing, and self-tests) and their motivation to learn in them.

13. Conclusion

This paper aimed to improve knowledge in two areas. First, it summarised the attributes of DGs that differently influenced learners' cognition, attitude and behaviour. The second goal was to present how researchers of the included studies measured participants' progress during or after playing DG. By presenting some features of games and how they have affected diverse learning outcomes, this paper offers helpful guidelines for designing an effective educational game. Furthermore, it extends the guidance by providing a general list of how educators have assessed students' progress after playing DGs. Instructional designers, educators, researchers, or anyone who is interested in educational games may determine first which type of outcome they desire for their students. They may consider the effective game features that are mentioned under each type of outcome. These features positively improved the desired outcomes according to studies included in this review. Students would then be naturally prepared for assessment without stress or cognitive load. After that, they could take into consideration the methods for measuring the learning outcomes. Combining game attributes to attain specific learning outcomes and assessment methods to measure players' progress was a specific purpose of this paper.

14. Limitations

The current review has several limitations. First, it was limited by the research terms and the databases used for retrieving full-text articles. Second, the range of participants' grades was broad. It included students from third grade to undergraduate students, covering studies over the last twenty years (2000–2020). A more focused study could yield different results.

15. Recommendations for Practice

From this review, DGs were found to be a beneficial intervention or scaffolding tool in the classroom for different learners' grades. Consequently, educators and teachers are encouraged to embrace the use of games to reach learning outcomes and cover subject matter at the learner's grade level. They might use free online educational games in the classroom or provide students with educational games' URL links for practising at home. They might also design and create their own DGs by combining effective game attributes along with the learning outcome. Furthermore, instructional designers should consider varied elements to design an effective game such as curriculum subject, learning objectives, learning outcomes, students' age, type of games and methods to assess progress and desired outcomes.

Many DGs have been created for Science and Math subjects. Most of the research shows positive progress in students' knowledge, attitude and skill after playing educational games. Other subjects where games could be used are Social Studies and History. In addition, alternative assessment methods could be used while learners play a DG, such as voice recognitions or motion tracking.

16. Recommendations for Future Research

Based on the findings of this review, a small amount of research related to the impact of games on students' behaviours was found. Furthermore, studies that examined students' behaviours and playing performance employed "action" and "puzzle" games, while employing "simulation" or "role playing" games would be more effective in terms of practising the learned knowledge and skills. Simulation or role-playing games provide more chances for players to practice a specific performance or train a special action. For example, some simulation games are about driving or flying things, while role-playing games involve a quest or rescuing someone or something, which requires a player to acquire tools or experience through game action (Prensky, 2001). Additionally, there were no simulation games in science although science topics are rich with experiments that require practical activities. Those experiments and activities could be conducted more safely and allow for more practice if simulation games were adopted. Practising within a simulation game might influence students' knowledge, scientific skills or scientific inquiry. More research needs to be conducted in this area. A similar lack of research suggests the need to examine the potential impact of playing strategy games for Math topics. Strategy games put the player in charge of something significant, such as an army, society or company (Prensky, 2001). The player may be the person responsible for a marketing or sales department, which is a relevant field for mathematical tasks in real life.

17. References

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