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Examining the characteristics of game-based learning: A content analysis and design framework

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ABSTRACT

The purpose of this study was to analyze the design characteristics of game-based learning environments in the research literature through a content analysis. Article text was coded in 194 sampled publications on six primary characteristics and 14 secondary characteristics from 2007 to 2017. The results revealed associations between four groups of primary characteristics for a framework including leveled games, problem solving games, open-world multiplayer games, and immersive multiplayer games. The framework of secondary characteristics included paired positive and negative game mechanics, immediate feedback with technology, reward mechanisms that track progress, supportive multi-sensory learning, team structures, and teams with personalization. We conclude the article with a discussion of primary and secondary characteristics in game-based learning, suggestions for reporting game-based learning research, and directions for future research.

1. Introduction

Game-based learning (GBL) can be defined as gameplay that incorporates educational objectives (Dickey, 2011; Hung, Yang, Hwang, Chu, & Wang, 2018; Plass, Homer, & Kinzer, 2015). The integration of games for learning can take many forms, from a computer game played in one class period to a semester-long roleplaying game covering an entire curriculum. GBL can keep students engaged and motivated (Annetta, Minogue, Holmes, & Cheng, 2009), and lead to deeper learning through an immersive environment in which students explore concepts, reflect on personal experience, and solve problems (Wiburg, Chamberlin, Trujillo, Parra, & Stanford, 2016).

Learning through gameplay includes cognitive, motivational, emotional, and social benefits (Boyle et al., 2016; Granic, Lobel, & Engels, 2014), but drawing conclusions from the current body of literature is challenged by a lack of systematic research that can be methodologically and theoretically combined to support design decisions (Mayer, 2016). This is evident in the ongoing call to develop common terms and frameworks for generalizability in GBL (Hainey, Connolly, Boyle, Wilson, & Razak, 2016; Plass et al., 2015; Vandercruysse; Vandewaetere, & Clarebout, 2012; Young et al., 2012).

Although design, in general, is a key component of several GBL models, there is insufficient differentiation within the models to

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address the variations of games (see Plass et al., 2015; Van Staalduinen & de Freitas, 2011). For example, the drill and practice format of the classic computer game Math Blaster! rewards learners for correct math facts in increasing levels of difficulty (Rodrigo, 2011). In comparison, the mobile augmented reality game Pokémon Go is situated within a rich narrative and connects learners to the global community through collaborative, location-based battles (Marquet, Alberico, & Hipp, 2018). The diversity of game design and game implementation are a significant challenge for researchers and practitioners looking to translate research into development and testing of effective learning games.

Researchers have repeatedly stated that the development of a GBL framework is broadly applicable if created from the perspective of the design of games. In 1985, Lepper presented the theoretical issues within a new technological paradigm, computers in schools, including how the design of games can be a foundation for studying motivation, interest, and learning. The author stated that framing research in the design of motivating software, such as learning games, "provides a common context in which the concepts and principles initially developed within several historically distinct research traditions can be systematically and simultaneously studied" (p. 3). The repeated call to examine games through the lens of design continues 30 years later. For example, Gaydos (2015) concluded, "attending to design may help bring together the various perspectives that have already been applied to games. Explicitly defining design theories and improving how we share our design knowledge should enable the development of common artifacts and processes, a necessary first step for replicating findings, iterating on solutions, and moving research across disciplines" (p. 481).

Echoing this perspective, Plass et al. (2015) suggested that a "more promising method to capture the uniqueness of game-based or playful learning can be found by focusing on how these learning environments are designed" (p. 262). In that respect, a GBL framework based on design would provide researchers with a foundation to examine how game characteristics work together and how individual game applications are unique.

Multiple studies have reviewed the literature to contribute to the growing body of knowledge on the impact of gameplay on learning. Although the results of these studies are positive indicators of the efficacy of GBL, they continue to conclude that the design of the game has a large influence on outcomes. The review by Boyle et al. (2016) discussed how game design can influence learning outcomes, in particular collaboration and competition, and recommended additional work to define game characteristics and systematically evaluate effects through multiple measures. Although particular game characteristics have been repeatedly identified as fundamental to GBL environments (Abdul Jabbar and Felicia, 2015; Bedwell, Pavlas, Heyne, Lazzara, & Salas, 2012; Malone & Lepper, 1987), this study takes the next step by providing empirical evidence of the use of those characteristics and how they interact together.

We are at a critical point in the field of GBL where there are a large number of publications to support an empirical analysis of design characteristics. Now, the development of a framework situated in the design of learning games can move past theoretical discussion and into an evidence-based conceptualization. Therefore, this study aimed to analyze the characteristics of GBL design through content analysis methodology. As a contribution to the field, the current study analyzed more than a decade of research to

Table 1
Comparison of the Design Characteristics in the GBL Literature and resulting model (left column).

Primary and Secondary Characteristics	Malone and Lepper (1987)	Bedwell et al. (2012)	Plass et al. (2015)	Abdul Jabbar and Felicia, 2015
Learning Support *Tutorial, Support, Challenge*[a]	Challenge *Uncertain Outcomes* *Self-esteem* *Cognitive curiosity*	Conflict/Challenge *Adaptation* *Challenge* *Surprise*	Learning mechanics	Challenges Obstacles Quests Problems/scenarios Scaffolding Built-in learning tools Mini-games Offline help tools
Assessment *Reward, Penalty, Feedback*	Recognition *Performance feedback*	Assessment *Assessment* *Progress*	Assessment mechanics Incentive System	Rewards
Learner Control *Control over Gameplay, Game Choice*	Control	Control *Control* *Interaction (equipment)*		Control/choices
Immersion *Sensory Element, Digital Immersion*	Curiosity *Sensory curiosity*	Action Language Immersion Environment *Language/ communication* *Sensory Stimuli*	Musical Score Aesthetic Design	Audio Visuals Video Text
Interaction *Collaboration, Competition, Other Communication*	Cooperation Competition	Human Interaction *Pieces/players* *Representation* *Interpersonal* *Social* *Conflict*		Virtual characters/ environments
Narrative	Fantasy	Game Fiction *Fantasy* *Mystery*	Narrative	Narrative/storyline Role-play

[a] Secondary-characteristics are italicized.

present a framework of primary and secondary design characteristics. The framework may provide designers with a blueprint for creating learning games and lay the foundation for researchers to examine the most effective combinations of design elements. In the next section, the method is presented in detail followed by results, discussion, and implications for researchers and practitioners.

2. Materials and method

2.1. Content analysis

Content analysis is the systematic examination of text or communication for the purpose of drawing conclusions about its meaning (Neuendorf, 2017). In education, content analysis has been used for a wide variety of research goals, including understanding trends in the education and technology research literature (Zawacki-Richter and Latchem, 2018; Bozkurt et al., 2015; Shih et al., 2008). Within the umbrella of content analysis, this study used pattern analysis to identify common elements in the text of published articles on GBL. This approach centers on similarities in the research literature as a foundation for coding and analysis (Krippendorff, 1980).

Methods for content analysis, including data collection, data analysis, and interpretation of data, are guided by theoretical models and expert knowledge of the researchers. In this study, the content analysis was conducted by six researchers with a familiarity of GBL and similar academic backgrounds to maintain consistency in coding interpretation (Krippendorff, 1980). The research team was led by a university faculty member with 10 years of experience teaching, researching, and publishing on the topic of GBL, and the remaining team members were PhD students within a GBL research group.

The variables for analysis were derived from the research literature using a grounded approach (Neuendorf, 2017). The research team identified empirical research with frameworks or models describing the characteristics of learning games. Applying a constant comparison method, articles were reviewed until theoretical saturation was reached (Bowen, 2008). The characteristics were organized into areas of conceptual agreement, resulting in a model with six primary characteristics and 13 secondary characteristics (Table 1). Concepts that were not supported in multiple studies were removed from the list.

2.2. Codebook development and validation

The model was developed into a codebook that included instructions for coding, clear descriptions of each item, and a scoring rubric for the primary characteristics (Appendix A). Two of the six researchers did not participate in the development of the codebook, addressing developer bias in content analysis (Lacy, Watson, Riffe, & Lovejoy, 2015). The codebook was validated by experts in the field of GBL to help determine the completeness and clarity of the research instrument (Neuendorf, 2017; McKenzie, Wood, Kotecki,

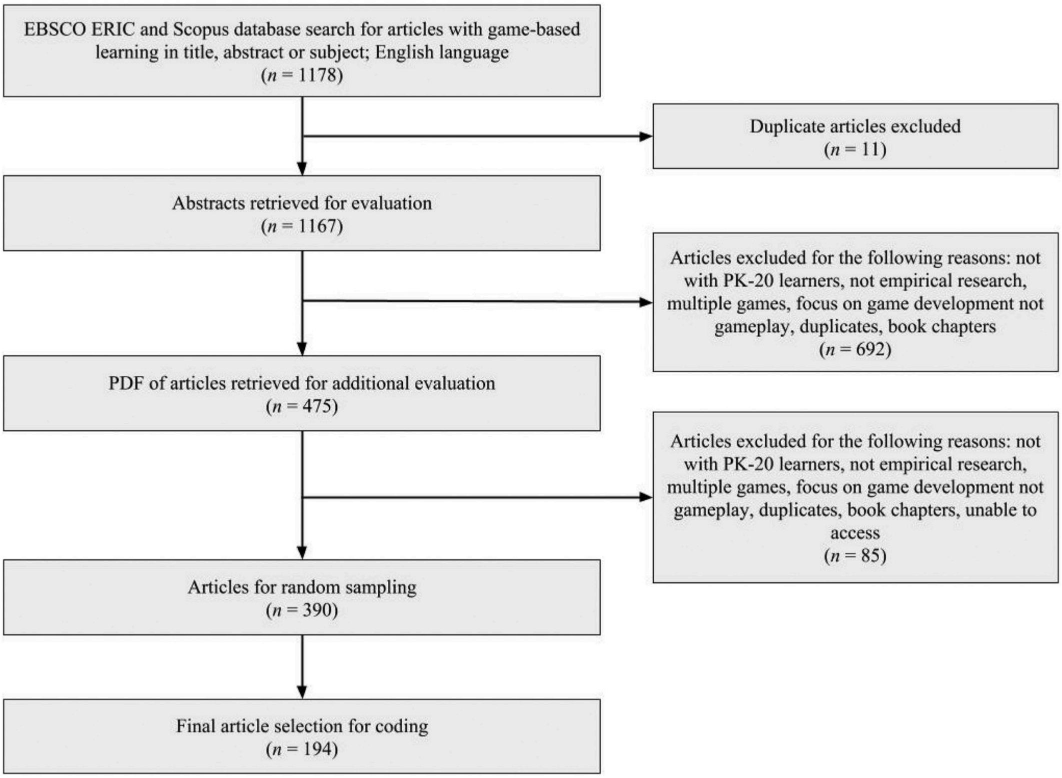

Fig. 1. Article evaluation protocol.

Clark, & Brey, 1999). The validation participants' expertise included experience creating, researching, or evaluating learning games.

2.3. Article sampling

This study utilized electronic abstract and citation databases to identify research articles identified as *game-based learning* in the title, abstract, or keyword. The articles were retrieved from two databases to test the completeness of the search: Scopus, currently the largest multidisciplinary academic database, and EBSCO ERIC, a large database of education research. The search resulted in 1178 articles with 11 duplicate articles, with the publication dates ranging as early as 2005 through 2017. The articles were subjected to multiple rounds of review to include empirical research with PK-20 learners playing a single game (Fig. 1).

Sampling of the articles allowed the research team to manage the extensive work of coding while maintaining a representative sample of the population (Krippendorff, 1980). The final selection was determined through a random sample of the 390 articles at a 95% confidence level with a 5% margin of error, resulting in 194 articles for inclusion in the study.

2.4. Coding procedures

The study was designed not fully crossed, with the articles assigned to one coder ($n = 127$) or two coders ($n = 67$) to allow a subset of the sample to be evaluated for inter-rater reliability (Hallgren, 2012). In order to determine how many articles should be assigned to multiple coders, we used the Lacy and Riffe (1996) sample size calculation in determining an 85% agreement for coder representation. This method is recommended by Lacy and colleagues as more accurate than using a percentage of articles for a reliability check.

First, coders were instructed to independently read and code the articles (i.e., introduction to conclusion) using the secondary characteristics (see Table 1). Second, they were instructed to score the GBL environment on the six primary characteristics using the rubric. This process occurred in five rounds over a four-month period. Coders were asked to review less than five articles per day to prevent coder fatigue, and they were asked to attend group checkpoints to review inter-rater reliability between each round (Lacy et al., 2015).

2.5. Coding reliability

To determine the reliability of the variables, we calculated both Krippendorff's Alpha (Kalpha) and percent agreement. Kalpha is appropriate for multiple coders assigned different units of analysis, consistent with the design of this study (Hallgren, 2012). The resulting Kalpha ranged from 0.71 to 0.87, and although three coefficients were below the 0.80 standard, a difficult coding task can reduce the acceptable level of Kalpha as low as 0.67 (De Swert, 2012; Table 2). In this study, the rubric items included a level of interpretation (e.g., "there is some evidence of control or choice in this game") making exact matches between coders difficult. In measuring inter-rater reliability of rubrics, percent agreement and adjacent agreement (i.e., scoring within one level above or below) are most commonly reported (Jonsson and Svingby, 2007). In this study, the adjacent agreement of 99–100% indicated a high level of consistency between coders.

3. Results

3.1. Demographic review of the sampled articles

The sampled articles were published between 2007 and 2017. The original data set included four articles published from 2005 to 2006, but they were not selected in the random sample. The number of articles generally increased each year, ranging from 2 in 2007 to 40 in 2017. The academic levels for the articles included early childhood and elementary school ($n = 31$), middle school ($n = 33$), high school ($n = 45$), university ($n = 79$), and other adult training ($n = 6$). The majority of studies were conducted in Asia ($n = 88$), followed by Europe ($n = 53$) and North America ($n = 42$).

Almost all articles described using some form of technology to deliver or facilitate the GBL environment. This included computer games (63%), mobile phone games (9%), game consoles (9%), and virtual or augmented reality (6%). Some games were delivered through multiple technologies (10%), but only a few games used little or no technology (3%; e.g., board games).

The articles spanned all nine of the ISCED educational groups (UNESCO Institute for Statistics, 2011). The greatest focus of learning content included the category of Science (41%; science, math, computer science), followed by General Programmes (14%; basic skills,

Table 2
Reliability coefficients of primary characteristic.

Criteria	Krippendorff's Alpha	95% Confidence interval	% Agreement	% Adjacent Agreement
Assessment	0.79	[.76, .82]	65	99
Learner support	0.71	[.67, .76]	64	99
Learner control	0.82	[.79, .85]	64	99
Immersion	0.72	[.65, .78]	74	99
Interaction	0.87	[.84, .89]	67	100
Narrative	0.84	[.80, .87]	68	99

literacy, and personal development), Humanities and Arts (13%), Social Sciences, Business, and Law (11%), and Health and Welfare (8%). The groups Services, Engineering, Manufacturing and Construction, Agriculture, and Education were 5% or less of the total sample.

3.2. Primary characteristics

3.2.1. Frequency of primary characteristics

The frequency of rubric scores is presented in Table 3, illustrating the variability of design in learning games. For example, scores of 1 or 2 indicated little or no evidence of that specific characteristic in the description of the game. The majority of articles were rated at this low level for Immersion, Interaction, and Learner Control. Conversely, few articles scored a 4 or 5, which would require evidence of the characteristic and any secondary characteristics in multiple areas or all areas of the game. Assessment, narrative, and interaction received the most 4 and 5 ratings. Although each characteristic was present in a majority of the articles, interaction and learner control were the least emphasized by authors when discussing the game environment. Overall, the six characteristics were well represented in GBL research studies.

3.2.2. Relationship between primary characteristics

A Spearman's rank-order correlation was run to assess the relationship between primary characteristics using the ordinal scores from the rubric. Applying the Hemphill (2003) interpretation of correlation coefficients, there was a statistically significant and small correlation between assessment and immersion, immersion and learner control, and immersion and learning support. There was a significant and moderate correlation between immersion and interaction, learner control and interaction, learning support and assessment, learning support and learner control, narrative and immersion, narrative and interaction, and narrative and learner control (Table 4). The associated items with moderate effect sizes are summarized in Fig. 2 into four groups of associated characteristics.

3.3. Secondary characteristics

3.3.1. Frequency of secondary characteristics

The secondary characteristics provided a more nuanced documentation of strategies used in GBL environments, particularly those identified in the literature as impactful for learning. In comparison to our rubric, in which coders applied scores for all articles in each category, the secondary characteristics were only coded when specifically discussed by authors in the articles (Table 5). Although all secondary characteristics were coded at some point in the sample, coding frequency varied greatly. Challenge, Feedback, and Reward were present in more than half of the articles, and Tutorial, Collaboration, Game Choice, Competition, and Other Communication were present in less than one third of the articles.

3.3.2. Relationship between secondary characteristics

The association between secondary characteristics (i.e., code present or absent) was determined through a Phi coefficient calculation and application of the Rea and Parker (1992) interpretation of values. The results were a statistically significant but weak association between multiple pairs: tutorial and support, tutorial and competition, support and collaboration, support and other communication, challenge and reward, challenge and penalty, penalty and feedback, control over gameplay and game choice, game choice and other communication, digital immersion and control, collaboration and other communication, and other communication and narrative (Table 6). The association was significant and moderate for the relationship between penalty and reward, feedback and reward, support and sensory element, digital immersion and feedback, collaboration and choice, and collaboration and competition. There was a significant but small negative association between tutorial and competition, and control over gameplay and digital immersion. Fig. 3 lists the six groups of associated secondary characteristics with moderate effect sizes.

4. Discussion

4.1. Primary characteristics framework

Data analysis on the primary characteristics resulted in four groups that can provide evidence of the types of games enacted for

Table 3
Percent of articles coded at each level of the primary characteristic rubric and mean rubric scores.

	% Score 1	% Score 2	% Score 3	% Score 4	% Score 5	Mean	Std. Deviation
Assessment	11	23	38	23	5	2.86	1.04
Immersion	6	51	33	10	1	2.48	0.78
Interaction	35	21	28	16	2	2.29	1.14
Learner Control	29	27	31	10	2	2.27	1.04
Learning Support	8	27	51	14	1	2.74	0.83
Narrative	22	25	36	14	3	2.52	1.08

Table 4
Primary characteristics correlation coefficients.

Variable	M	SD	1	2	3	4	5
1. Assessment	2.86	1.04					
2. Immersion	2.48	0.78	.183[a]				
3. Interaction	2.29	1.14	.017	.235[b]			
4. Learner Control	2.27	1.04	.114	.164[a]	.274[b]		
5. Learning Support	2.74	0.83	.269[b]	.151[a]	.092	.233[b]	
6. Narrative	2.52	1.08	-.044	.289[b]	.216[b]	.295[b]	.104

[a] $p < 0.05$ level.
[b] $p < 0.01$ level.

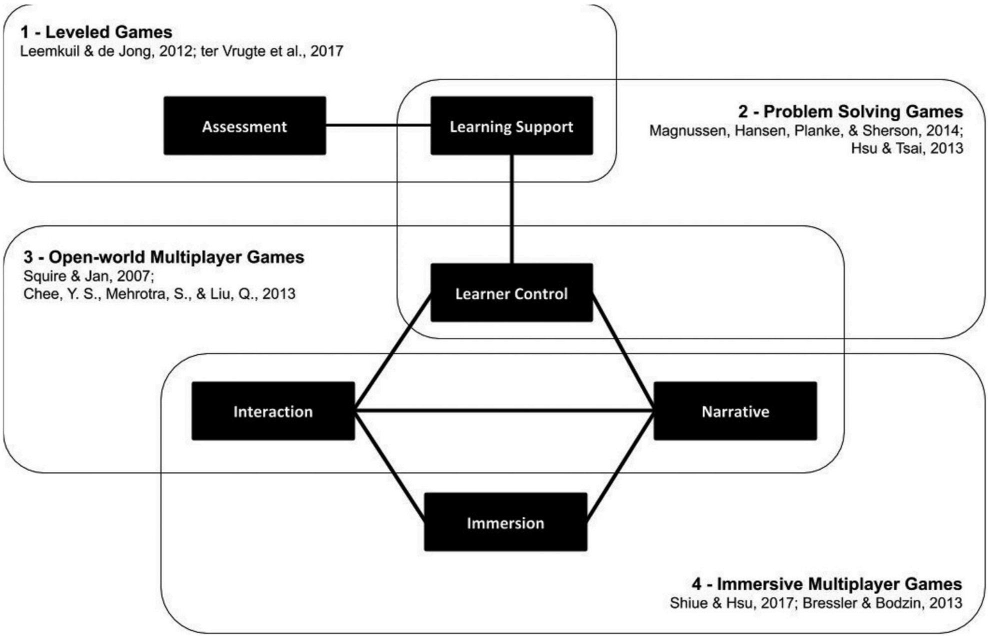

Fig. 2. Framework of associated primary characteristics with moderate effect sizes and example articles.

learning in the research literature: leveled games, problem solving games, open-world multiplayer games, and immersive multiplayer games (see Fig. 2).

In GBL, assessment is fundamental to play (Ifenthaler, Eseryel, & Ge, 2012) and an integral component of measuring student knowledge or skills growth (Huber & Skedsmo, 2016; Snyder, 2010). Assessment during gameplay can occur from the beginning to the end of a game and includes any form of feedback on the players' knowledge, skills, and abilities (Plass et al., 2015). Learning supports adapt the game to players with different skill levels, with assistive content, practicing gameplay skills, and orienting teams. Learning support mechanisms interrelate with motivational, cognitive, as well as social learning factors to help players succeed, enjoy, and continue in the game (Abdul Jabbar and Felicia, 2015; Plass et al., 2015). They introduce players to the gaming environment, ensure that players know what to do in the game, and provide resources on how to accomplish goals. Types of learning supports includes guidance on game mechanics (Plass et al., 2015), adaption to players' performance and skills (Bedwell et al., 2012; Malone, 1981; Peirce & Wade, 2010; Wilson et al., 2009), and scaffolding (Jabbar & Felicia, Ke, 2013; Plass et al., 2015).

Leveled games such as the *Zeldenrust* (ter Vrugte et al., 2017) and *KM Quest* (Leemkuil, de Jong, de Hoog, & Christoph, 2003) reflect the association between learning support and assessment as identified in the framework. Zeldenrust is a two-dimensional, educational computer game that consists of three types of subgames with support features such as tutorials and feedback. Faded worked examples that were provided in the form of feedback were found to improve GBL when teaching proportional reasoning skills (ter Vrugte et al., 2016). In addition, simulation games like KM Quest, a knowledge management game, provided adaptive advice that supported players by giving warnings and hints. It was found that the feedback provided in the form of advice in the KM Quest management game focused attention on problems after they have occurred (Leemkuil & De Jong, 2012).

Problem solving games combining learning support and learner control can be best described as open-ended spaces that allow players the freedom to explore, but also guide learning in solving a problem. In this case, learner control helps to create a sense of power within the gaming environment (Bedwell et al., 2012; Cordova & Lepper, 1996; Garris; Ahlers, & Driskell, 2002). A feeling of command allows the player to decide how they use tools and puzzles in the game as well as motivates them to continue playing

Table 5
Coding application examples.

Characteristic	Secondary Characteristics	% of Articles with code	Example Coded Text
Learning Support	Tutorial	31	The goal of the first lesson was to orient the students in the digital environment and teach them how to interact with one another appropriately (Pusey & Pusey, 2015)
	Support	46	If the student fails to correctly answer the question the second time, the learning system then presents the correct answer and the link for accessing the details of the learning target (Hwang, Wu, Chen, & Tu, 2016)
	Challenge	71	The game included three levels (1, 2, and 3), as shown in Fig. 2. These levels represented increasing levels of difficulty and contextual feedback for learning (Chen, Wang, & Lin, 2015)
Assessment	Reward	57	If the given answer was correct, the bubbles and the sealed door disappeared, and the player could progress to the next question (Nebel, Schneider, Beege, & Rey, 2017)
	Penalty	37	When the children blasted elastic objects, the game encouraged them with a “Yoho” sound, and if they blasted the wrong object, there was a “No” sound to alarm them (Savari, Ayub, Wahab, & Noor, 2016)
	Feedback	58	The collected performance data of individual student was plotted as a performance chart and returned to the student for their reference (Ma, 2013)
Learner Control	Control over Gameplay	45	The open-ended context of the game allowed the students to face problems at their own pace, moving forward and backward when needed (Monjelat, Méndez, & Lacasa, 2017)
	Game Choice	28	The players could choose from three types of tools, namely grenades, machine guns, and hammers to destroy the buildings (Ma, 2013)
Immersion	Sensory Element	34	The audio portion of the game consists of a spoken introduction to the premise of the game, space-age background music, and weird sounds emanating from the mutants (Greer, Lin, & Atkinson, 2017)
	Digital Immersion	49	The purpose of the present study was to investigate the learning effect of a GBL system that was developed by location-based and mixed reality technologies (Doong, Lai, Chuang, & Hsu, 2015)
Interaction	Collaboration	31	Student teams have to work together and achieve the goals set for each complex task scenario by applying their learning in math, bioscience, geography, geology, social studies, and literacy (Eseryel, Ge, Ifenthaler, & Law, 2011)
	Competition	26	Games are designed to assess knowledge acquisition through small group competition, allowing learners to absorb the instructional content without pressure (Lu & Liu, 2015)
	Other Communication	26	In addition, chatting and interacting with other people through the virtual environment were rated as fun activities by two students (Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009)
Narrative	Narrative	70	The narrative background is told to the players in a short intro showing how the players stranded on the island (Wendel, Gutjahr, Göbel, & Steinmetz, 2013)

Table 6
Correlation between secondary characteristics.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Tutorial													
2.Support	.156[a]												
3.Challenge	.047	-.042											
4.Reward	-.132	.043	.151[a]										
5.Penalty	.016	.052	.161[a]	.289[b]									
6.Feedback	-.102	.066	.096	.240[b]	.166[a]								
7.Control over Gameplay	.052	.034	-.071	-.007	-.047	-.047							
8.Game Choice	.025	-.087	-.054	-.091	.101	.059	.150[a]						
9.Sensory Element	.076	.212[b]	-.134	.005	.087	.101	-.042	.015					
10.Digital Immersion	.003	-.033	.134	.034	.048	.265[b]	-.147[a]	.128	.015				
11.Collaboration	.091	.156[a]	-.099	-.043	-.077	-.057	.119	.273[b]	.053	.025			
12.competition	-.145[a]	.049	-.086	.128	.091	.069	.102	.107	-.100	.036	.236[b]		
13.Other Communication	.066	.155[a]	.036	-.025	-.048	.035	.066	.115	.083	.048	.168[a]	-.126	
14.Narrative	-.067	.104	.123	-.019	.099	.018	.120	.054	-.054	.077	-.019	-.001	.172[a]

[a] $p < 0.05$ level.
[b] $p < 0.01$ level.

(Cordova & Lepper, 1996). For example, the game studied by Hsu and Tsai (2013) engaged elementary age children in navigating an avatar and a virtual flashlight to save a princess, along with reflective questions when the player was not successful in the task. The Hsu and Tsai (2013) study illuminated that not all interventions are successful in impacting learning goals, and the design of the learning support mechanism may influence student outcomes.

The two combinations with multiplayer aspects center on the characteristics of interaction and narrative. Narrative is the storyline that provides contextual information for learning (Bedwell at al., 2015; Plass et al., 2015) and creates game cohesion by helping players to relate to the story (Tan, Goh, Ang, & Huan, 2013), understand the situation they experience in the game, and motivate them to continue to play (Plass et al., 2015). The term interaction in this study focused on two-way interactions with other players or with virtualized characters in the game. Specifically, in these interactions the player maintains a responsive relationship with the computer

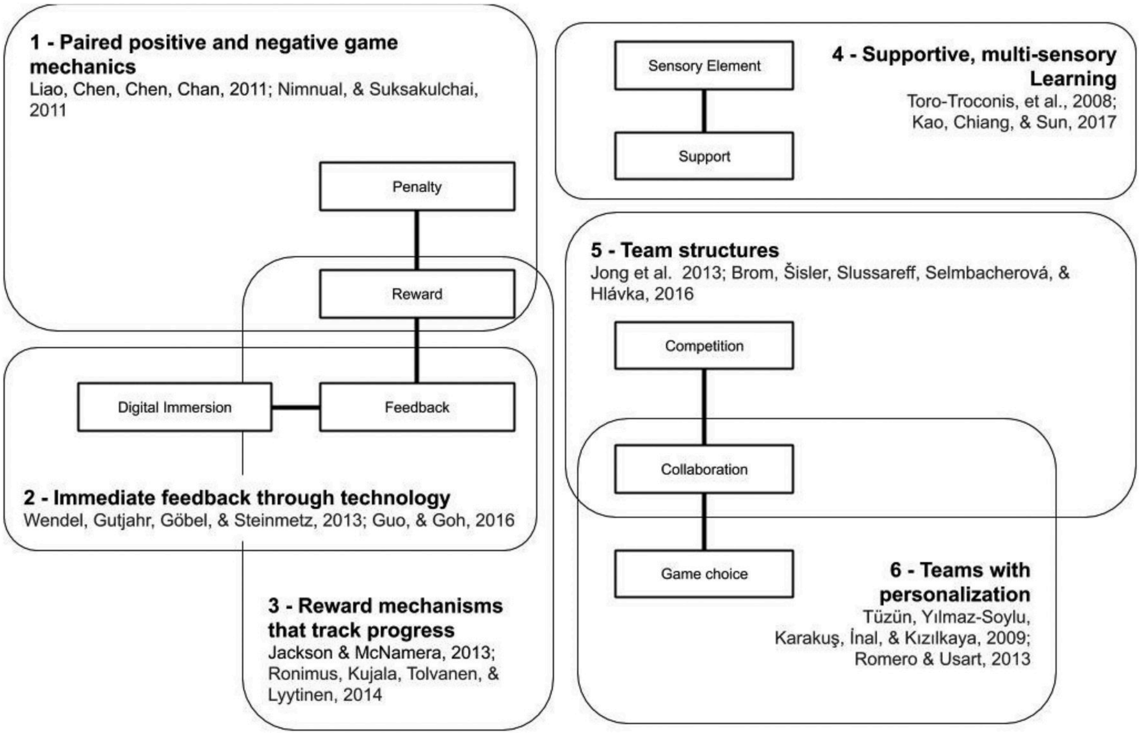

Fig. 3. Framework of associated secondary characteristics with moderate effect sizes and example articles.

or other players. Hence, the cognitive and emotional engagement that occur through interaction in gameplay can result in higher levels of learning (Pivec, Dziabenko, & Schinnerl, 2003; Romero, Usart, Ott, Earp, & de Freitas, 2012).

Within multiplayer games, there were two variations. First, open world games emphasized learner control allowing players to have choice and manipulate some of the game features (Bedwell et al., 2012; Garris, Ahlers, & Driskell, 2002). The sense of control over the gaming activity and the choice that players have can lead them to experience higher levels of interaction and motivation (Bedwell et al., 2012; Jabbar & Felicia, 2015), as well as to engage in collaborative and competitive gaming activities (Peterson, 2012; Romero, Usart; Ott, & Earp, 2012). For example, the Mad City Mystery mobile location-based game allowed learners to choose a role, determine a path in the game, collaborate and compete with peers, and follow the complex storyline. The experience resulted in the students demonstration of scientific skills and collaborative behaviors, with varied results for learners in different age groups (Squire & Jan 2007).

Second, immersive games included sensory input or digital technology, where learners perceive to be physically present in the narrative of the game (de Freitas et al., 2010; Jennett et al., 2008), have no fear of real-life consequences, (Wilson et al., 2009), and lack awareness of time (Jennett et al., 2008). In the game *Library Scape*, learners take a role and practice information literacy skills (Guo & Goh, 2016). This game provides feedback and support to students through an affective embodied agent which had a positive impact on the students' motivation and enjoyment to learning, as well as in their confidence of their knowledge and skills.

4.2. *Secondary Characteristics Framework*

This study also coded articles for secondary characteristics that further describe the specific actions or thematic styles of gameplay. The results of our research indicated six associations between secondary characteristics (Fig. 3). These particular combinations are frequently paired together in a balanced design of a game (Adams, 2014), such as penalty and reward and collaboration and competition. Researchers have begun to classify and list these characteristics (see Arnab et al., 2015; Alaswad & Nadolny, 2015), but there is a need to examine patterns and outcomes associated with these game features.

Rewards were associated with two different combinations in the secondary characteristic framework. Rewards are useful in motivating learners to continue playing as a mechanism to provide positive feedback for accomplishing a task. In the first combination, rewards are correlated with penalty (Fig. 3). For example, a player may be rewarded at different tiers for completing a level in a certain amount of time, but they can also be penalized for taking too long to complete a game. The second combination of characteristics include rewards and feedback. Rewards that display progress such as earning a badge for completing a level, increased student learning (Filsecker & Hickey, 2014), though results can vary based on student motivational tendencies (Auvinen, Hakulinen, & Malmi, 2015; Barata, Gama, Jorge, & Gonçalves, 2017). Results in studies examining reward systems like experience points and extra challenges indicated that a variety of rewards are important to capture the interest of the wider player audience (Bernik, Radošević, & Strmečki, 2017).

The relationship in the framework between feedback and digital immersion is to be expected, as the use of technology can improve the efficiency and individualization of information. In the 3D immersive game *Escape from Wilson Island*, the player interface included health meters measuring key player attributes (Wendel et al., 2013). The meters dynamically changed as the learner progressed towards game goals. Another common digital feedback mechanism in games are leaderboards, a tool to rank students against one another in course points or other achievements. The use of leaderboards can have negative results for learners (Nicholson, 2013), particularly if the same students occupy the top of the leaderboard.

It is interesting to note that the sensory element characteristic was connected with support, with both items tightly linked with the design of the game. Sensory elements, whether visual (e.g., arrows on the ground to guide player direction), auditory (e.g., warning sound; indications of success or failure; cues for a boss encounter), or haptic (e.g., rumble in a controller to indicate the player is straying off course in a racing game or taking damage in an action game) are meant to provide the player with support in navigating the game environment, indicating player performance, or just add to the overall narrative of the game. Although audio is frequently considered last when designing a game, it "can be incredibly powerful. Audio feedback is much more visceral than visual feedback, and more easily simulates touch." (Schell, 2008, p. 351). The game *Crayon Physics Deluxe* exemplifies the importance of sensory information by including videos for struggling learners and visual clue for those needing assistance in playing the game. Different combinations of these support features resulted in positive but unique learning outcomes (Kao, Chiang, & Sun, 2017), supporting the importance of designing with learning goals and outcomes in mind (Nadolny, Alaswad, Culver, & Wei, 2017).

Collaboration appears in two categories of the secondary characteristic framework, teamwork with personalization and team structures. Collaboration is when real or virtual teams work together toward a common goal (Malone & Lepper, 1987). When a group collaborates and is able to control the methods by which their team performs, higher occurrences of interaction and motivation are achieved (Bedwell et al., 2012; Jabbar & Felicia, 2015). Additionally, engagement in gameplay by means of personalization can create cognitive and emotional investment through the interaction with the game. Increased interaction and the value placed on teamwork can help students to obtain positive learning outcomes (Pivec et al., 2003; Romero et al., 2012). Communication between teammates in pursuit of shared goals can support learning and increase player satisfaction (Plass et al., 2015).

4.3. Implications for practice

Taken together, the Primary and Secondary Frameworks guide instructional designers, game designers, and educators in both selecting and creating learning games. This can be done by taking an outcomes-based approach to designing game-based learning experiences (Anderson & Krathwohl, 2001). By starting the process with end goal in mind, the educator can select games that are structured to support the learning required for success. In Table 7, we align cognitive outcomes to the frameworks and commercially available games. For example, the focus of leveled games was primarily on the remembering, understanding, and applying processes. Games in this category were designed with levels or challenges with increasing difficulty in content knowledge, such as the *DragonBox* math games (Siew, Geofrey, & Lee, 2016). In this category, an educator can expect to see rewards (e.g., points, stars, unlocks) or penalties that work towards winning the game. In comparison, educators wanting to support the student evaluating and creating processes may seek to include open-world multiplayer games (OWMG). These games were built with the capacity for teamwork and with the freedom to control the path through the game. The popular game *Minecraft Education Edition* exemplifies the characteristics of OWMG through learner control, narrative, and interaction, and it is supported by a rich educator community (Nebel, Schneider, & Rey, 2016).

Game designers, including educators creating their own classroom games, are provided a blueprint for four distinct game types in Table 7. After determining learning outcomes (e.g., plan and test a biology experiment), designers can systematically develop learning activities that integrate the game characteristics (e.g., Problem Solving Game) to create a more motivating and engaging learning experience. While the learning outcomes provide an overarching scheme of what players or learners will be expected to accomplish at the end of the game, the primary and secondary characteristics can be combined to not only facilitate learning processes, but also to

Table 7
Design Guidelines for games using the Primary and Secondary Characteristics Frameworks.

Cognitive Outcomes	Game Type	Primary Characteristics	Secondary Characteristics	Example Games
Recognize, Recall, Interpret, Identify, Classify, Differentiate	Leveled Game	Assessment Learning Support	***Reward***[a]***, Penalty, Feedback****, Tutorial,* ***Support****, Challenge*	DragonBox Algebra, We The Jury, Stack the States
Organize, Plan, Infer, Differentiate, Classify, Execute, Test	Problem Solving Game	Learner Control Learning Support	*Control Over Gameplay,* ***Game Choice,*** *Tutorial,* ***Support****, Challenge*	Portal, Microsoft Flight Simulator, Terraforming Mars
Organize, Plan, Hypothesize, Exemplify, Produce, Create	Open-world Multiplayer Game	Interaction Learner Control Narrative	***Collaboration, Competition****, Other Communication, Control Over Gameplay,* ***Game Choice,*** *Narrative*	Minecraft, Dungeons and Dragons, World of Warcraft
Recall, Interpret, Identify, Organize, Plan, Classify, Execute, Test	Immersive Multiplayer Game	Interaction Immersion Narrative	***Collaboration, Competition****, Other Communication,* ***Sensory Element****, Digital Immersion, Narrative*	Pokémon Go, Diner Duo VR, Prodigy

[a] Bold Items are within the Secondary Characteristics Framework.

develop other learning skills (e.g., teamwork, effective communication). Our design guidelines are intended to give educators a clear perspective on the complex and multiple ways that game-based learning can be leveraged.

Whether the artifact is an educational game or a gamified learning environment, players and learners will benefit from a sound integration of these characteristics frameworks that connect theoretical insights with research-based design.

4.4. Implications for research

This study provides the impetus for further research in a variety of areas. First, by laying the groundwork for the primary and secondary characteristics associated with game-based learning, research can be conducted to examine the educational effectiveness of the characteristics, singularly, or in various combinations. Research can point to whether learning effectiveness may be a direct result of the incorporation of one or more of the characteristics as a form of motivation for better game-play, leading to improved outcomes. Importantly, future studies can apply the consolidated list of terms (see Table 1) when describing the design characteristics of games for a common vocabulary.

Second, almost all research articles reported using some form of digital technology, but few at higher levels of immersion. This is of particular interest because it appears that GBL studies are missing opportunities for immersive gameplay and three-dimensional interaction with content and other players. As noted in the literature immersive gameplay can have several educational benefits, such as enabling multiple perspectives where players can change their frames of reference, situated learning where learners experience authentic real-life contexts, and transfer of knowledge and skills into actual real-world settings (Dede, 2009). Conversely, table-top games (e.g., board game or dice game) have a historic representation in education that is not evident in the research literature. We encourage researchers to also conduct studies on the design and evaluation of non-digital games for learning.

Finally, the combination of primary and secondary characteristics may help map out learning paths that are more personalized, motivating, and potentially effective for learning. Our findings, however, do not provide a right combination of characteristics or prescribe the types of games that are most effective. The implications we draw center on intentional efforts to design more effective games (Plass et al., 2015; Qian & Clark, 2016) by leveraging the multiple patterns that can be threaded to support learning.

4.5. Limitations

This study relied on the authors of the articles to communicate design strategies and features, and we found that many studies were not sufficiently clear or thorough in describing the game environment. As a result, the primary limitation in our study was that games were only coded based on text, descriptions, and figures. Descriptions in articles varied significantly in length and depth, with some articles containing little information about the actual games involved in the study. It is clear that better descriptions of the game design are needed, especially for games made specifically for their respective study, and not widely available, off-the-shelf type games (Gaydos, 2015).

We call for a higher standard for reporting GBL design in the research literature that systematically utilizes a GBL rubric such as the one developed in the current paper when describing the gaming context of a study. A consistent set of descriptors in publications would help authors in better identifying factors in games that contribute to learning and ensure that adequate game information is provided in papers. Specifically, we recommend GBL articles include standard information about the GBL environment.

1. The presence, role and duration of each primary characteristics in gameplay.
2. The presence of secondary characteristics and any significant interactions between the game and players.
3. The game demographic and implementation information (e.g., genre, academic content area or skills, use of technology, duration of gameplay, and screenshots or video of gameplay).
4. The contextual information about the GBL environment, including teacher observation if in classroom settings.

5. Conclusion

Design is at the root of the evaluation of games, and the research on the learning that happens during gameplay is complex and multifaceted. The content analysis in this study resulted in two frameworks of design characteristics in GBL. The primary characteristics include four distinct categories of learning games, while the secondary characteristics provides six associations that describe key features of the game.

Attending to design provides more than just interesting information for other researchers, but the necessary contexts and content to make valid claims and test generalizability of gaming interventions. Through more thorough and consistent reporting of the design of learning games, researchers will have access to the quality of information necessary for larger studies and meta-analyses. Future research that combines evaluation and reporting of the design of GBL, along with learning outcomes of gameplay, will accelerate the potential impacts of gaming in education. Additionally, focusing on the two frameworks can guide designers in creating novel experiences for learners grounded in the research literature.

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None.

CRediT authorship contribution statement

Larysa Nadolny: Conceptualization, Supervision, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Asimoula Valai:** Methodology, Investigation, Writing - original draft, Writing - review & editing. **Nadia Jaramillo Cherrez:** Investigation, Writing - original draft, Writing - review & editing. **Doug Elrick:** Methodology, Investigation, Writing - original draft, Writing - review & editing. **Alison Lovett:** Methodology, Investigation, Writing - original draft, Writing - review & editing. **Matthew Nowatzke:** Investigation, Formal analysis, Writing - original draft, Writing - review & editing.

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Appendix A. Supplementary data

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