Student Game Design as a Literacy Practice: A 10-Year Review

Hsiu-Ting Hung[1], Jie Chi Yang[2*] and Yi-Chin Tsai[1]

[1]Department of English, National Kaohsiung University of Science and Technology, Taiwan // [2]Graduate Institute of Network Learning Technology, National Central University, Taiwan // hhung@nkust.edu.tw // yang@cl.ncu.edu.tw // 0431813@nkust.edu.tw

[*]Corresponding author

ABSTRACT: Learning through designing digital games has recently emerged as a potential approach for school learners to boost their literacy development and learning in and across disciplines. However, existing knowledge on this relatively new approach is still fragmented, and little is known about its implementation features, associated learning opportunities, and possible challenges experienced by students. As such, the present review seeks to synthesize relevant research in terms of the three aspects stated above to better understand the concept of student game design as a literacy practice. A total of 30 peer-reviewed research articles published between 2010-2020 are included in this research synthesis. Findings reveal that there is considerable variation in how the literacy learning approach of student game design is currently implemented, with respect to the school learners involved and game-making tools adopted. Despite its diverse nature, the feasibility of literacy learning by game-making is confirmed across the reviewed studies, with the disciplinary literacy in computer science and 21st century literacy being most prominent. This review has also brought to light the potential of introducing students to content-based game design to foster interdisciplinary learning. In order to provide a balanced portrait, this review further identifies major challenges of learning with the game-making approach from students' perspectives.

Keywords: Digital games, Game design, Literacy learning, Literature review

1. Introduction

There has been widespread recognition of the need for educators to re-conceptualize what it means to be literate, and how literacy learners can be educated to succeed in the 21st century (Mills, 2010; Trilling & Fadel, 2009). While the traditional notion of literacy centers on print-based practices of reading and writing, recent understanding of literacy is tightly linked to a repertoire of practices for functioning well in context-specific settings, which are mediated and shaped by technology in some way in this digital era (Gilster, 1997; Kress, 2003; Lankshear & Knobel, 2003). Arguably, literacy is now best understood as a broad range of socially organized practices that extend the traditional reading and writing skills. It follows that literacy can be practiced in varying forms for different purposes in a variety of sociocultural contexts, hence new literacies (Street, 1998) or multiliteracies (Cope & Kalantzis, 2000). Some notable examples addressed in this study are 21st century literacy (Trilling & Fadel, 2009), new media literacy with respect to digital game design (Buckingham & Burn, 2007), and disciplinary literacy in various subjects, such as computer science and social studies (Shanahan & Shanahan, 2008).

In line with the reconceptualization of literacy, educators and researchers are continually looking for innovative ways to help students learn effectively with digital technologies. Among the various options, digital games have been suggested as promising catalysts. In the book entitled "*What video games have to teach us about learning and literacy,"* Gee (2003) identifies 36 principles from cognitive science that are situated in games. For example, the active learning principle states that all aspects of the digital game-based learning environment are designed to encourage active student learning. Over the years, research interest in digital games has grown, and many of Gee's (2003) claims about the affordances of learning through game-playing have been supported by empirical studies. Research has shown that exposing students to well-designed gaming environments with appropriate instructional support can enhance their learning motivation (Hawlitschek & Joeckel, 2017), vocabulary acquisition (Franciosi, 2017), problem solving (Eseryel, Law, Ifenthaler, Ge, & Miller, 2014), and disciplinary literacy (Chen, Wong, & Wang, 2014). This strand of research promotes the approach to learning by playing digital games, which is taken as an initial effort to explore game-related applications in education (Boyle et al., 2016; De Freitas, 2018; Hung, Yang, Hwang, Chu, & Wang, 2018).

Building further on the educational potential of game use from a different perspective, a recent trend has seen the introduction of a game-making approach "in which games are designed by students (rather than professionals) for

learning benefits" (Kafai & Burke, 2015, p. 314). This approach is rooted in constructionist learning theories (Papert, 1980, 1991). It highlights the role of students as active learners as they take part in the process of constructing their own digital games (Prensky, 2008), and thereby constructing meaningful knowledge and experience for themselves (Kafai & Resnick, 2012). Various benefits of learning with the game-making approach have been shown in empirical studies, such as enhancing student game designers' creative thinking (Navarrete, 2013), improving their computer science knowledge and programming skills (Denner, Werner, & Ortiz, 2012), and actively engage them in the process of learning by design (Topalli & Cagiltay, 2018). Although there appears to be an increasing number of studies on student game design in recent years, this body of research is still small (Reynolds, 2016). Scholars have therefore called for more studies and reviews in order to more fully grasp the value of the game-making approach (Kafai & Burke, 2016; Kordaki & Gousiou, 2017). The present study is an endeavor in response to this call.

The purpose of this study is to provide a scoping review of empirical studies that adopt the game-making approach in educational contexts, using a content analysis of multiple aspects. Of central interest to this review are literacy practices of school learners across different levels of education, ranging from kindergarten to university (also known as K-16). Therefore, the first aspect analyzed here is student game designers' educational levels. This information is helpful to determine suitable settings for future implementations. Another related aspect is the existing tools for non-experts to design digital games for the sake of schooling. This is the practical information that allows educators to choose appropriate game design tools that best suit their target learners' needs. In addition to contextual features, researchers are generally interested in understanding what learning opportunities are available to students and what learning challenges are facing students as they are involved in the creation of digital games. While empirical evidence on the contributions and constraints related to the game-making approach is still inconclusive, review results of these aspects are intended to enhance the current knowledge base. Accordingly, the following research questions are analyzed in this review.

- What is known about the student game designers' educational levels and game design tools when learning with the game-making approach?
- What is known about the opportunities offered by the game-making approach for literacy learning?
- What is known about the challenges of learning with the game-making approach from students' point of view?

2. Related work

Several previous reviews informed this work. Li and Tsai (2013) reviewed 31 empirical studies published between 2000 and 2011 regarding the use of digital games in science education. The sample was identified through the databases of SCOPUS and Web of Science. The results revealed that most of the studies adopted the game-playing approach to facilitate students' science learning, and only two studies utilized the game-making approach for the same purpose. Learning gains in scientific knowledge were found to be the most dominant outcome, followed by problem solving skills.

Another related review by Kordaki and Gousiou (2016) was conducted in the context of computer science education. One of its main purposes was to examine the effects of a specific genre, digital card games, on student learning. Of the 24 articles spanning 2003-2013 that were located by database searches (e.g., ACM, ERIC, and IEEE), two-thirds asked students to learn by designing their own games, and one-third exposed students to game-playing environments for learning. Positive effects of both game uses were reported, with most centering on the acquisition of programming knowledge and skills.

In a follow-up study, Kordaki and Gousiou (2017) expanded the scope of their prior review from the domain-specific context of computer science to various application domains. A similar methodology was utilized to sample a total of 50 articles with varying game uses (game-making: n = 14; game-playing: n = 35; both: n = 1). The results provided evidence to support applications of digital card games in education in general, with computer science, language, and science being the most common disciplines.

Focusing on the learning benefits of the game-making approach, Kafai and Burke (2015) carried out a literature review to analyze research evidence on student game design in terms of personal, social, and cultural dimensions in K-12 education. The literature search sources included electronic databases, journal archives, and conference archives. Based on the review results of the 55 articles published in 1995-2015, it was found that the game-making

approach contributed most to one's growth in the personal dimension. Leading the way were studies that documented students' learning of coding, followed by the learning of other content areas, such as mathematics and science.

The four reviews mentioned above, although differing in focus, all agree in suggesting the feasibility of integrating digital games in education through the game-making approach. They have raised attention to the still evolving concept of student game design in various disciplinary contexts. To advance in this direction, the present review was motivated to synthesize research findings on the use of digital game design as a literacy practice for school learners.

Kafai and Burke's (2015) review is of particular relevance to this study. They synthesized research findings published up to 2015, and proposed a useful framework for organizing learning benefits of student game design along three different dimensions: personal, social, and cultural. Reflecting the continuing interest in the game-making approach, the present review attempts to provide a more up-to-date understanding of the relevant studies published during the past 10 years (2010-2020). Furthermore, what this review adds is a tighter focus on learning outcomes related to the personal dimension, but with a broader perspective of literacy learning in K-16 education. This review is especially propelled by new literacy studies (e.g., Gee, 2003; Kress, 2003; Mills, 2010), and thus is concerned with the emerging forms of literacy and the interdisciplinary learning potential beyond (traditional) learning of coding. More importantly, this review seeks to address the research gap identified by Kafai and Burke (2015), stating that more documentation on possible challenges pertaining to student game design is needed in the literature. With these thoughts, the present review is therefore conducted to offer a more balanced understanding by attending to some contextual, positive, and negative aspects of student game design, as specified in the previously stated research questions.

3. Method

3.1. Search keywords and sources

The search keywords for the present review included ("game design" OR "game construction" OR "game making" OR "game development") AND (learning OR learners OR students). They were developed according to the purpose of this study, with reference to the previously discussed reviews. The keywords were searched for in titles, abstracts, and author-specified keywords as a preliminary to locating potential articles from a large body of literature in a set of prescribed sources, as specified below.

Three sources of data for the literature search were involved in this review, including electronic databases, journal archives, and reference lists of relevant literature. The methodological decision to go for these search sources was made by consulting relevant publications on guidance for undertaking systematic reviews (Horsley, Dingwall, & Sampson, 2011; Petticrew & Roberts, 2008).

In the digital era, it is commonly believed that searching electronic databases is the most efficient approach to collect data for review studies. Because *ScienceDirect* is one of the largest and most heavily used databases in Taiwan (Ke, Kwakkelaar, Tai, & Chen, 2002), where the authors conducted this study, it was selected as the primary search source for data retrieval.

With an understanding that not all journals are covered by *ScienceDirect*, several refereed journals were also searched. These included: *British Journal of Educational Technology*, *Educational Technology Research and Development*, and *Educational Technology & Society*. They were collectively utilized as the secondary search source due to their reputation as leading journals in the field of education and educational technology, and also for the reason that prior reviews on digital game-based learning (e.g., Hwang & Wu, 2012) have chosen these journals to form their datasets.

Checking reference lists of relevant literature is another avenue to increase the yield of data in review studies, as exemplified by Kafai and Burke's (2015) research synthesis on student game design. Therefore, the reviewed studies cited in the references of the aforementioned reviews (i.e., Kafai & Burke, 2015; Kordaki & Gousiou, 2016; Kordaki & Gousiou, 2017; Li & Tsai, 2013) were manually searched in a snowballing manner as a supplement to the other two search sources of this review.

3.2. Inclusion criteria

Five inclusion criteria were applied during full-text reading of potentially relevant articles to further determine the relevance of a reported study to the present review.

- The study was published during the review period of January 2010 to April 2020.
- The study was reported in a peer-reviewed journal with the Social Science Citation Index (SSCI).
- The study had to be presented as a full-length research article with a robust methodology.
- The study involved K-16 students as the primary participants or game designers.
- The study focused on the use of the game-making approach to facilitate students' literacy learning in some way.

Common examples of excluded articles were those not published during the designated period, those not reported in SSCI journals, those without clear indications of well-designed empirical studies, those focusing on game design by teacher learners or professional game developers rather than school learners, and those addressing other approaches of game use, such as student learning through digital gameplay.

3.3. Coding categories

The coding category of student game designers' educational levels documented the participating students' grade levels based on the K-16 educational system. This was divided into four sub-categories: kindergarten, primary school (grades 1~6), secondary school (grades 7~12), and tertiary or higher education (grades 13~16). A sub-category of mixed was used for studies that recruited participants with different educational levels across settings.

The coding category of game design tools referred to the specific authoring technologies through which the participating students created their own digital games in the reviewed studies. This was not prescribed but allowed for bottom-up emergence in the reviewed studies. A total of 16 game design tools were observed. For those studies without a clear indication of game-making tools, a separate sub-category of unspecified was applied.

The coding category of literacy forms were open coded given the diverse focus of literacy research and the multifaceted nature of literacy. A total of five sub-categories were identified in this review, including (1) basic literacy, (2) intermediate literacy, (3) advanced or disciplinary literacy, (4) 21st century literacy, and (5) new media literacy with respect to digital game design.

The first three sub-categories of literacy forms reflected the traditional understanding of literacy development within disciplines (Shanahan & Shanahan, 2008). Basic literacy, typically acquired in early childhood, referred to the most fundamental skills for being literate in a language, such as reading, writing, and numeracy. Intermediate literacy was defined as the more complex cognitive skills beyond the basic level, which involved domain-specific developmental abilities (e.g., computational thinking in computer science) or domain-general abilities (e.g., analyzing, evaluating, and deep learning strategies). Advanced or disciplinary literacy was considered as specialized knowledge and skills in various subjects or content areas, such as mathematics and science.

The last two sub-categories of literacy forms reflected the contemporary understanding of literacy learning. The so-called 21st century literacy referred to a set of higher-order thinking skills that could be learned and applied across disciplines (Boltz, Henriksen, Mishra, & Deep-Play Research Group, 2015; Conklin, 2011; Trilling & Fadel, 2009). These included, but were not limited to, problem solving, perspective taking, creative thinking, and critical thinking skills. Another relatively new form of literacy that emerged in this review was new media literacy, or more specifically, game design literacy. It was viewed as the ability to properly use and design digital games to express themselves and make meaning out of their learning experiences (Buckingham & Burn, 2007).

As for the coding category of literacy learning orientation, a distinction was made between monodisciplinary and interdisciplinary to understand whether multiple specialized branches of knowledge and skills were embodied in literacy learning and development (Ashby & Exter, 2019). The former referred to a literacy learning orientation that centered on the acquisition of a single branch of knowledge and skills within its disciplinary tradition. An example is teaching students to program a game as a means of helping them develop the targeted computational thinking and programming skills in a computer science course. The latter was an orientation of literacy learning that involved more than one branch of knowledge and skills across traditional disciplinary boundaries. For example, students in a

game design course may design a content-based digital game for history learning, through which to develop their disciplinary literacies in history and computer science.

In answering the last research question, the reviewed studies were initially coded according to whether or not they reported students' perceived challenges when learning with the game-making approach. Details of this category were then inductively coded and analyzed using a thematic analysis approach (Nowell, Norris, White, & Moules, 2017) in order to identify major themes of interest that emerged from the students' point of view. As it turned out, five sub-categories pertaining to the major themes of student perceived challenges were formed.

3.4. Triangulation of literature selection methods

To enhance the research credibility, this study generally followed Petticrew and Roberts' (2008) guidelines for conducting systematic literature reviews in social science, and used multiple methods for data triangulation. First, the keyword-based selection method was adopted to obtain potential articles from the three major sources of data (described in Section 3.1), and 371 articles were initially identified. Next, the criterion-based selection method was utilized to screen the full-texts of all the potentially relevant articles against the five inclusion criteria (described in Section 3.2), and 52 of them remained. Last, the coding-based selection method was employed to assess the eligibility of the shortlisted articles. Two researchers (co-authors of the study) performed this task individually to content analyze each article by applying the coding categories (described in Section 3.3). The inter-coder reliability of the initial analytical results was high (85%). Any coding conflicts were resolved by involving a third researcher through discussion to reach consensus among the research team. Eventually, a final sum of 30 articles were systematically reviewed and reported in this work.

4. Results and discussion

The 30 studies on learning by game-making were included as the review sample, involving a combined total of 2,366 student participants (see Table 1). It was observed that these studies were distributed across various journals, with *Computers & Education* (n = 13) being the most common publication venue, followed by *Educational Technology Research and Development* (n = 7).

4.1. Contextual features of the game-making approach

Table 2 outlines the two contextual features of the game-making approach analyzed in this review. The analytical results pertaining to learners' educational levels indicated that this approach was most frequently applied in secondary education (n = 14), followed by elementary education (n = 6). As expected, this approach was least used with kindergarten students (n = 1) due to its prerequisite of access and ability to learn with technology. Among the five studies with mixed learner groups from different educational levels, one study (Strawhacker & Bers, 2018) recruited children in kindergarten through second grade as participants, and the others (Bossavit & Parsons, 2018; Çakır, Gass, Foster, & Lee, 2017; Papavlasopoulou, Giannakos, & Jaccheri, 2019; Reynolds & Caperton, 2011) recruited participants mostly from middle/high schools. Taken together, most of the reviewed studies involved secondary school learners. Such a finding is contradictory to previous reviews (Kordaki & Gousiou, 2016; Kordaki & Gousiou, 2017) that suggested the frequent use of game-making approach in tertiary or higher education contexts. This is probably due to the difference of years included in this review (2010-2020) and in the previous reviews (2003-2013). It can be inferred that, under the overarching influence of educational digitalization, the game-making approach has been gradually reaching out to younger populations in recent years compared with in the past.

Based on the evidence obtained in this review, teaching and learning with the game-making approach appears more suitable for secondary school learners (and beyond), as they have mastered fundamental literacy skills before moving onto the complex tasks of digital game creation (Kafai & Burke, 2016; Moje, 2015). This finding suggest that when working with younger learners, such as elementary and even kindergarten students, teachers may consider simplifying the technology component in game design so as to lessen students' cognitive load.

Researchers' selection of game-making tools was very diverse, given the 16 different tools identified across the 30 reviewed studies. The most popular tools among the pool were Scratch (n = 6) and Kodu (n = 5), followed by high-end game development engines, including RPG Maker (n = 2), Flash (n = 2), and Neverwinter Nights (n = 2). Other game-making tools were comparatively less popular (n = 1 for each). It further appears that a game design tool is more likely to be selected over others if: (1) it is made available free of charge, and even specifically designed for instructional purposes, as in the cases of Scratch by MIT Media Lab (Ke, 2014) and Kodu by Microsoft (Akcaoglu, 2014); (2) it supports object-oriented visual programming techniques, which is considered more friendly and intuitive for novice learners/programmers (Topalli & Cagiltay, 2018); and (3) it allows for 3D creations, which is deemed more appealing to students (Akcaoglu & Green, 2018).

Among the wide array of the game design tools observed in this review, Scratch and Kodu are comparatively more affordable technologies for learners across different age groups. It is because these two tools are freely accessible, visually appealing, and easy to use. As a result, Scratch and Kodu are suggested as good starting points for educators and researchers interested in the game-making approach, particularly when working with learners with limited or no programming background.

Table 1. List of the reviewed studies and their sample sizes

Study ID	Reviewed studies	Number of participants
S01	Akcaoglu (2014)	18
S02	Akcaoglu and Green (2019)	35
S03	Akcaoglu and Koehler (2014)	44
S04	Allsop (2016)	30
S05	An (2016)	12
S06	Bossavit and Parsons (2018)	6
S07	Çakır et al. (2017)	21
S08	Carbonaro, Szafron, Cutumisu, and Schaeffer (2010)	50
S09	Denner et al. (2012)	59
S10	Dishon and Kafai (2020)	16
S11	Feng and Chen (2014)	232
S12	Gallagher and Grimm (2018)	53
S13	Hava, Guyer, and Cakir (2020)	15
S14	Howland and Good (2015)	55
S15	Hwang, Hung, and Chen (2014)	167
S16	Kalmpourtzis (2019)	34
S17	Kao, Chiang, and Sun (2017)	126
S18	Ke (2014)	64
S19	KovačEvić, Minović, Milovanović, de Pablos, and StarčEvić (2013)	125
S20	Molins-Ruano et al. (2014)	80
S21	Navarrete (2013)	12
S22	Øygardslia and Aarsand (2018)	9
S23	Papavlasopoulou et al. (2019)	157
S24	Reynolds and Caperton (2011)	199
S25	Robertson (2012)	25
S26	Ruggiero and Green (2017)	11
S27	Strawhacker and Bers (2019)	57
S28	Topalli and Cagiltay (2018)	322
S29	Vos, van der Meijden, and Denessen (2011)	235
S30	Yang and Chang (2013)	67
Total	30	2,366

Table 2. Student game designers' adopted tools and educational levels identified in the reviewed studies

Study ID	Game design tools	Student game designers' educational levels				
		Kindergarten	Elementary	Secondary	Tertiary	Mixed
S01	Kodu			X		
S02	Kodu			X		
S03	Kodu			X		
S04	Alice		X			
S05	Gamestar Mechanic			X		
S06	Microsoft Kinet					X
S07	Unity					X
S08	Neverwinter Nights			X		
S09	Stagecast Creator			X		
S10	Scratch & Makey Makey			X		
S11	Scratch		X			
S12	Portal				X	
S13	Kodu			X		
S14	Flip programming language			X		
S15	Kodu		X			
S16	Adobe AIR	X				
S17	Crayon Physics Deluxe			X		
S18	Scratch			X		
S19	Unspecified				X	
S20	C programming language				X	
S21	Flash			X		
S22	RPG Maker		X			
S23	Scratch					X
S24	Flash					X
S25	Neverwinter Nights		X			
S26	Unspecified			X		
S27	Scratch					X
S28	Scratch				X	
S29	Memory Spelen		X			
S30	RPG Maker			X		
Total	16	1	6	14	4	5

4.2. Literacy learning opportunities offered by the game-making approach

Table 3 displays the associated opportunities for literacy development and learning resulting from the use of the game-making approach. A glance at the literacy learning orientations makes it clear that this approach is more achievable as a monodisciplinary (n = 20) than interdisciplinary (n = 10) literacy practice, with computer science being the core disciplinary literacy. Among those studies conducted in monodisciplinary contexts, the development and learning of computer science literacy is generally targeted at the advanced level. In previous reviews (Kordaki & Gousiou, 2016; Kordaki & Gousiou, 2017), similar frequency patterns were observed. It was actually not surprising to find that the development of disciplinary literacy in computer science was the most common literacy learning opportunity available to students due to the nature of digital game design concerning computer skills and domain-specific knowledge of basic programming concepts. One typical example was the study by Howland and Good (2015), in which 55 secondary school students spent eight weeks learning to design their own 3D role-playing games using a simplified programming language, Flip. Comparison of the individual students' pre- and post-tests was used to determine their development with respect to programming knowledge and skills. The results showed that learning-by-game-design was capable of significantly improving the students' disciplinary literacy in computer science.

Delving into the progression of literacy development within disciplines, several studies investigated students' intermediate level of thinking and learning skills (n = 4). For instance, the game-making approach was found to facilitate the students' domain-specific abstraction and reading skills in computer science (Carbonaro et al., 2010; Strawhacker & Bers, 2019) and various domain-general thinking skills, such as organizing, evaluating, and deep

learning skills (e.g., Allsop, 2016; Vos et al., 2011). Only one study (Kalmpourtzis, 2019) applied the game-making approach through the expert-guided use of Adobe AIR in combination with low-tech prototypes to improve kindergarten students' basic level literacy, in this case pre-algebraic patterning.

The review results also revealed the interdisciplinary learning potential of the game-making approach. One-third of the 30 reviewed studies (n = 10) were classified as literacy research with an interdisciplinary learning orientation because they integrated literacy practices of computer science and another discipline. These included two studies each in physics (Gallagher & Grimm, 2018; Kao et al., 2017) and history (Molins-Ruano et al., 2014; Øygardslia & Aarsand, 2018) as well as one study each in mathematics (Ke, 2014), biology (Yang & Chang, 2013), geography (Bossavit & Parsons, 2018), science (Hwang et al., 2014), social studies (An, 2016), and foreign language (Vos et al., 2011). Taking An's (2016) study as an example, seventh graders were engaged to incorporate social studies content into their game design projects using Gamestar Mechanic. The students commented that this interdisciplinary learning experience helped them review what they had previously learned in their social studies class (as design content) through hands-on realization of computer literacy in the form of digital games (as design artifacts). These research instances generally reveal that interdisciplinary learning opportunities enabled by the game-making approach were abundant but selective, as different studies may vary greatly with respect to outcome variables of interest in specific research contexts.

Table 3. Literacy forms and literacy learning orientations identified in the reviewed studies

Study ID	(Traditional) literacy forms			(New) literacy forms		Literacy learning orientation	
	Basic literacy	Intermediate literacy	Advanced literacy	21st century literacy	Game design literacy	Mono-disciplinary	Inter-disciplinary
S01				X		X	
S02				X		X	
S03				X		X	
S04		X				X	
S05			X	X			X
S06			X				X
S07			X			X	
S08		X	X			X	
S09			X			X	
S10				X		X	
S11			X	X		X	
S12			X	X			X
S13				X		X	
S14			X			X	
S15			X	X			X
S16	X			X		X	
S17			X		X		X
S18			X				X
S19			X			X	
S20			X				X
S21				X		X	
S22			X				X
S23			X			X	
S24			X			X	
S25					X	X	
S26				X		X	
S27		X				X	
S28			X			X	
S29		X	X				X
S30			X	X			X
Total	1	4	19	13	2	20	10

In addition to the benefits of cultivating students' traditional literacy development in and across various disciplines, the review results showed that the game-making approach was applicable to developing the learning of so-called new literacy practices, including 21st century literacy (n = 13) and game design literacy (n = 2). For instance, learning by game-making in Yang and Chang's (2013) study was implemented to develop students' 21st century literacy with a focus on critical thinking and their domain-specific academic achievement in biology. In another study that adopted the same approach (Kao et al., 2017), the students' learning outcomes were assessed in terms of physics knowledge acquisition and game design literacy.

Among those studies addressing students' 21st century literacy, problem solving was most frequently examined, with eight of the 13 relevant studies being identified (Akcaoglu, 2014; Akcaoglu & Green, 2019; Akcaoglu & Koehler, 2014; Feng & Chen, 2014; Hava et al., 2020; Hwang et al., 2014; Kalmpourtzis, 2019; Ruggiero & Green, 2017). Other higher-order thinking skills were examined in sporadic studies, including two for creative thinking (Gallagher & Grimm, 2018; Navarrete, 2013), one for critical thinking (Yang & Chang, 2013), one for perspective taking (Dishon & Kafai, 2020), and one for systems thinking and the like (An, 2016). A possible explanation for this finding is that higher-order thinking skills are now gaining increasing attention in literacy education, since such skills are being recognized as essentials for helping students develop into lifelong learners who are competent in dealing with the life demands of the 21st century (Conklin, 2011; Trilling & Fadel, 2009).

While previous reviews have documented the positive effects of the game-making approach on literacy learning in various disciplines (Kafai & Burke, 2015; Kordaki & Gousiou, 2016; Kordaki & Gousiou, 2017; Li & Tsai, 2013), the present review further extends the potential of this approach to the development of 21st century literacy and new media literacy (exemplified by digital game design). This finding opens up new possibilities for literacy educators and researchers to explore various emerging forms of literacy related to the game-making approach. Moreover, educators need to be aware of the interdisciplinary learning potential of the game-making approach, and seek to embed it into a wider curriculum beyond the core discipline of computer science. Doing so may proactively prompt students to ponder the connectivity and interplay between two or more disciplinary literacies, while also nurturing the development of higher-order thinking and other emerging forms of literacy. Creation of content-based digital games is a concrete task that can be executed to achieve the desired outcomes. Following on from this point, it is argued that university students are better candidates than those in lower educational levels. This is largely due to the strong literacy foundation required to perform a complex and satisfactory task as planned (Ashby & Exter, 2019).

4.3. Students' perceived challenges of learning with the game-making approach

Table 4 specifies the studies explicitly reporting learners' accounts of their experience with the game-making approach according to the major themes of challenges which emerged from this review. While learning by making digital games has produced positive findings related to literacy practices in and across disciplines, it may also pose some challenges to participating students, which should not be overlooked. In light of this, each of the reviewed studies was inductively analyzed for students' perceived challenges, if any, based on the presence of relevant dependent variables expressed in the purpose statement and/or research questions. In this review, only a subset of 12 relevant studies out of the entire sample (n = 30) directly examined students' perspectives in this regard. These studies utilized mixed or qualitative methods to generate evidence from diverse data sources, such as interviews, classroom observations, reflection worksheets, open-ended survey questions, and game artifact analyses. As a result of inductive coding and analysis, five major themes were identified, including (1) technological challenges related to the operational use of game design tools, (2) unfamiliarity with game design principles and practices, (3) insufficient time for game design, (4) lack of instructional support during the learning-by-game-making process, and (5) weak or difficult integration of content knowledge into games. Each of these themes is briefly discussed below.

Half of the 12 relevant studies reported that many of the participating students encountered technological challenges as they created games using the designated tools (e.g., Navarrete, 2013). Results of a follow-up analysis revealed that such a technologically-oriented difficulty may be caused by, for example, the daunting task of coding in and of itself (Ke, 2014), the complexity of professional-grade game-making tools like Unity (Çakır et al., 2017), and learner differences, particularly children designers or learners who are less competent in computer literacy (Akcaoglu & Green, 2018). These impeding conditions should be taken into consideration so as to adequately select learner-friendly game-making tools in support of the game-making approach.

Another major challenge identified in this review was learners' unfamiliarity with game design tasks, with five of the 12 relevant studies falling into this category. It is generally agreed in these studies that design by itself is not a simple task, and undoubtedly the multiplicity of digital game design makes it even harder for students to manage. Consequently, assisting students in knowing what design is, what games are, and how these two can be conceptualized together is deemed a necessary first step (Reynolds & Caperton, 2011). Such learner training and preparation must be supplemented with hands-on explorations to prime students' systematic application of design ideas, game mechanics, and creative problem-solving techniques for them to effectively tackle unexpected difficulties (Akcaoglu & Green, 2018).

Time limitation was one common problem reported in three of the 12 relevant studies. From the students' perspective, creating digital games was very time consuming, and they were often overwhelmed by the complicated and iterative task of game design (KovačEvić et al., 2013). To eliminate this problem, enhancing students' time management skills may help them realize and implement their game design plans more efficiently. On the research side, it is recommended to apply the game-making approach in studies with longer durations, rather than one-shot or short-term investigations (lasting from hours to a few weeks).

Table 4. Major themes of student game designers' perceived challenges identified in the reviewed studies

Study ID	Explicit report: Yes/No	The five major themes				
		Technological challenges	Game design difficulties	Time limitations	Lack of support	Weak content integration
S01	No					
S02	Yes	X	X			
S03	No					
S04	No					
S05	Yes		X			X
S06	No					
S07	Yes	X		X		
S08	No					
S09	Yes				X	
S10	Yes					X
S11	No					
S12	No					
S13	Yes		X			
S14	No					
S15	No					
S16	No					
S17	No					
S18	Yes	X				X
S19	Yes			X	X	
S20	No					
S21	Yes	X				
S22	No					
S23	Yes	X				
S24	Yes	X	X	X	X	
S25	Yes		X			
S26	No					
S27	No					
S28	No					
S29	No					
S30	No					
Total	12	6	5	3	3	3

Three out of the subset of 12 relevant studies recognized students' need for guidance in the learning-by-game-making process as a priority area for improvement, particularly when adopting the game-making approach with those who had little or no experience in digital game design. Denner et al. (2012) found that novice game designers were

less likely to persist in the face of setbacks and challenges, and hence extensive instructional support was needed. On this point, some researchers (KovačEvić et al., 2013; Reynolds & Caperton, 2011) have suggested personal consultations and even co-designing with experts as possible solutions to overcome students' unfamiliarity with and uncertainty about what learning-by-game-making might actually entail.

As previously presented, only 10 out of the 30 reviewed studies were implemented with an interdisciplinary learning orientation, and even fewer (n = 3) explicitly examined students' difficulties as they learned with the game-making approach. In such studies, many participating students reported that connecting content knowledge to game design was the most challenging part of the learning experience. As shown in the cases of math game-making in Ke (2014) and historical game-making in An (2016), the students often felt perplexed about how to integrate two disciplines of specialized knowledge and skills in meaningful ways. According to Ke (2014), one strategy to avoid this situation is to provide focused training of content-specific design thinking so as to better prepare student game designers for this integrated intellectual challenge.

All in all, it is evident that digital game creation provides rich and ample literacy learning opportunities, while also bringing some challenges, for students to develop into competent literacy learners who are capable of meeting the societal expectations in today's increasingly competitive environment. Therefore, when implementing the game-making approach for literacy learning in and across disciplines, careful attention should be paid to reduce the common constraints identified in this review.

5. Conclusion

The present review has sought to contribute to the literature by spearheading the game-making approach that is beginning to flourish as a literacy practice in K-16 education. Encouragingly, learning by making digital games has been shown as a promising approach. Prominent reasons are that it is theoretically grounded in constructionist learning, empirically supported by the reviewed studies here, and practically in line with the digitalization of education in contemporary times. On the whole, the findings and implications derived from the present review are anticipated to shed light on the refinement of student game design in future practices.

As with all literature reviews, the sample of this study was limited by the use of search terms, search sources, and search methods for literature collection. The selection of relevant articles was further restricted to those published in SSCI journals during the past 10 years. Many potentially relevant works, particularly "grey literature" (e.g., unpublished dissertations and conference proceedings), were thus excluded from consideration. To complement the focus of this review, meta-analyses that synthesize both published and unpublished studies with a quantitative approach are especially needed to determine the effectiveness of student game design.

Acknowledgement

This study is sponsored in part by the Ministry of Science and Technology in Taiwan under the contract numbers MOST 106-2628-S-327-001-MY3, MOST 106-2628-S-992-303-MY3, and MOST 108-2511-H-008-010-MY3.

References

(References marked with an asterisk indicate studies reviewed in this work.)

*Akcaoglu, M. (2014). Learning problem-solving through making games at the game design and learning summer program. *Educational Technology Research and Development, 62*(5), 583-600.

*Akcaoglu, M., & Green, L. S. (2019). Teaching systems thinking through game design. *Educational Technology Research and Development, 67*(1), 1-19.

*Akcaoglu, M., & Koehler, M. J. (2014). Cognitive outcomes from the Game-Design and Learning (GDL) after-school program. *Computers & Education, 75*, 72-81.

*Allsop, Y. (2016). A Reflective study into children's cognition when making computer games. *British Journal of Educational Technology, 47*(4), 665-679.

*An, Y. J. (2016). A Case study of educational computer game design by middle school students. *Educational Technology Research and Development, 64*(4), 555-571.

Ashby, I., & Exter, M. (2019). Designing for interdisciplinarity in higher education: Considerations for instructional designers. *TechTrends, 63*(2), 202-208.

Boltz, L. O., Henriksen, D., Mishra, P., & Deep-Play Research Group. (2015). Rethinking technology and creativity in the 21st century: Empathy through gaming-perspective taking in a complex world. *TechTrends, 59*(6), 3-8.

*Bossavit, B., & Parsons, S. (2018). Outcomes for design and learning when teenagers with autism codesign a serious game: A Pilot study. *Journal of Computer Assisted Learning, 34*(3), 293-305.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An Update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178-192.

Buckingham, D., & Burn, A. (2007). Game literacy in theory and practice. *Journal of Educational Multimedia and Hypermedia, 16*(3), 323-349.

*Çakır, N. A., Gass, A., Foster, A., & Lee, F. J. (2017). Development of a game-design workshop to promote young girls' interest towards computing through identity exploration. *Computers & Education, 108,* 115-130.

*Carbonaro, M., Szafron, D., Cutumisu, M., & Schaeffer, J. (2010). Computer-game construction: A Gender-neutral attractor to Computing Science. *Computers & Education, 55*(3), 1098-1111.

Chen, M. P., Wong, Y. T., & Wang, L. C. (2014). Effects of type of exploratory strategy and prior knowledge on middle school students' learning of chemical formulas from a 3D role-playing game. *Educational Technology Research and Development, 62*(2), 163-185.

Conklin, W. (2011). *Higher order thinking skills to develop 21st century learners.* Huntington Beach, CA: Shell Education.

Cope, B., & Kalantzis, C. (2000). (Eds.). *Multiliteracies: Literacy learning and the design of social futures.* London, UK: Routledge.

De Freitas, S. (2018). Are games effective learning tools? A Review of educational games. *Educational Technology & Society, 21*(2), 74-84.

*Denner, J., Werner, L., & Ortiz, E. (2012). Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts? *Computers & Education, 58*(1), 240-249.

*Dishon, G., & Kafai, Y. B. (2020). Making more of games: Cultivating perspective-taking through game design. *Computers & Education, 148*, 103810. doi:10.1016/j.compedu.2020.103810

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An Investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology & Society, 17*(1), 42-53.

*Feng, C. Y., & Chen, M. P. (2014). The Effects of goal specificity and scaffolding on programming performance and self-regulation in game design. *British Journal of Educational Technology, 45*(2), 285-302.

Franciosi, S. J. (2017). The Effect of computer game-based learning on FL vocabulary transferability. *Educational Technology & Society, 20*(1), 123-133.

*Gallagher, D., & Grimm, L. R. (2018). Making an impact: The effects of game making on creativity and spatial processing. *Thinking Skills and Creativity, 28,* 138-149.

Gee, J. (2003). *What video games have to teach us about learning and literacy.* New York, NY: Palgrave Macmillan.

Gilster, P. (1997). *Digital literacy.* New York, NY: Wiley.

*Hava, K., Guyer, T., & Cakir, H. (2020). Gifted students' learning experiences in systematic game development process in after-school activities. *Educational Technology Research and Development*. doi:10.1007/s11423-020-09750-z

Hawlitschek, A., & Joeckel, S. (2017). Increasing the effectiveness of digital educational games: The Effects of a learning instruction on students' learning, motivation and cognitive load. *Computers in Human Behavior, 72,* 79-86.

Horsley, T., Dingwall, O., & Sampson, M. (2011). Checking reference lists to find additional studies for systematic reviews. *Cochrane Database of Systematic Reviews, 8*. doi:10.1002/14651858.MR000026.pub2

*Howland, K. & Good, J. (2015). Learning to communicate computationally with a Flip: A bi-modal programming language for game creation. *Computers & Education, 80*, 224-240.

Hung, H. T., Yang, J. C., Hwang, G. J., Chu, H. C., & Wang, C. C. (2018). A Scoping review of research on digital game-based language learning. *Computers & Education, 126*, 89-104.

*Hwang, G. J., Hung, C. M., & Chen, N. S. (2014). Improving learning achievements, motivations and problem-solving skills through a peer assessment-based game development approach. *Educational Technology Research and Development, 62*(2), 129-145.

Hwang, G. J., & Wu, P. H. (2012). Advancements and trends in digital game-based learning research: A Review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology, 43*(1), E6-E10.

Kafai, Y. B., & Burke, Q. (2015). Constructionist gaming: Understanding the benefits of making games for learning. *Educational Psychologist, 50*(4), 313-334.

Kafai, Y. B., & Burke, Q. (2016). *Connected gaming: What making video games can teach us about learning and literacy.* Cambridge, MA: MIT Press.

Kafai, Y. B., & Resnick, M. (2012). (Eds.). *Constructionism in practice: Designing, thinking, and learning in a digital world.* New York, NY: Routledge.

*Kalmpourtzis, G. (2019). Connecting game design with problem posing skills in early childhood. *British Journal of Educational Technology, 50*(2), 846-860.

*Kao, G. Y. M., Chiang, C. H., & Sun, C. T. (2017). Customizing scaffolds for game-based learning in physics: Impacts on knowledge acquisition and game design creativity. *Computers & Education, 113*, 294-312.

*Ke, F. (2014). An Implementation of design-based learning through creating educational computer games: A Case study on mathematics learning during design and computing. *Computers & Education, 73*, 26-39.

Ke, H. R., Kwakkelaar, R., Tai, Y. M., & Chen, L. C. (2002). Exploring behavior of E-journal users in science and technology: Transaction log analysis of Elsevier's ScienceDirect OnSite in Taiwan. *Library & Information Science Research, 24*(3), 265-291.

Kordaki, M., & Gousiou, A. (2016). Computer card games in computer science education: A 10 year review. *Educational Technology & Society, 19*(4), 11-21.

Kordaki, M., & Gousiou, A. (2017). Digital card games in education: A Ten year systematic review. *Computers & Education, 109*, 122-161.

*KovačEvić, I., Minović, M., Milovanović, M., De Pablos, P. O., & StarčEvić, D. (2013). Motivational aspects of different learning contexts: "My mom won't let me play this game…". *Computers in Human Behavior, 29*(2), 354-363.

Kress, G. (2003). *Literacy in the new media age.* London, UK: Routledge.

Lankshear, C., & Knobel, M. (2003). *New literacies: Changing knowledge and classroom learning.* Philadelphia, PA: Open University Press.

Li, M. C., & Tsai, C. C. (2013). Game-based learning in science education: A Review of relevant research. *Journal of Science Education and Technology, 22*(6), 877-898.

Mills, K. A. (2010). A Review of the "digital turn" in the new literacy studies. *Review of Educational Research, 80*(2), 246-271.

Moje, E. B. (2015). Doing and teaching disciplinary literacy with adolescent learners: A Social and cultural enterprise. *Harvard Educational Review, 85*(2), 254-278.

*Molins-Ruano, P., Sevilla, C., Santini, S., Haya, P. A., Rodríguez, P., & Sacha, G. M. (2014). Designing videogames to improve students' motivation. *Computers in Human Behavior, 31*, 571-579.

*Navarrete, C. C. (2013). Creative thinking in digital game design and development: A Case study. *Computers & Education, 69*, 320-331.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1-13.

*Øygardslia, K., & Aarsand, P. (2018). “Move over, I will find Jerusalem”: Artifacts in game design in classrooms. *Learning, Culture and Social Interaction, 19,* 61-73.

*Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2019). Exploring children’s learning experience in constructionism-based coding activities through design-based research. *Computers in Human Behavior, 99,* 415-427.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* New York, NY: Basic Books.

Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), *Constructionism* (pp. 1-12). Norwood, NJ: Ablex.

Petticrew, M., & Roberts, H. (2008). *Systematic reviews in the social sciences: A Practical guide*. Malden, MA: Blackwell.

Prensky, M. (2008). Students as designers and creators of educational computer games: Who else? *British Journal of Educational Technology, 39*(6), 1004-1019.

Reynolds, R. (2016). Defining, designing for, and measuring “social constructivist digital literacy” development in learners: A Proposed framework. *Educational Technology Research and Development, 64*(4), 735-762.

*Reynolds, R., & Caperton, I. H. (2011). Contrasts in student engagement, meaning-making, dislikes, and challenges in a discovery-based program of game design learning. *Educational Technology Research and Development, 59*(2), 267-289.

*Robertson, J. (2012). Making games in the classroom: Benefits and gender concerns. *Computers & Education, 59*(2), 385-398.

*Ruggiero, D., & Green, L. (2017). Problem solving through digital game design: A Quantitative content analysis. *Computers in Human Behavior, 73,* 28-37.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review, 78*(1), 40-59.

*Strawhacker, A., & Bers, M. U. (2019). What they learn when they learn coding: investigating cognitive domains and computer programming knowledge in young children. *Educational Technology Research and Development, 67*(3), 541-575.

Street, B. (1998). New literacies in theory and practice: What are the implications for language in education? *Linguistics and Education, 10*(1), 1-24.

*Topalli, D., & Cagiltay, N. E. (2018). Improving programming skills in engineering education through problem-based game projects with Scratch. *Computers & Education, 120,* 64-74.

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times.* San Francisco, CA: Jossey-Bass.

*Vos, N., van der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education, 56*(1), 127-137.

*Yang, Y. T. C., & Chang, C. H. (2013). Empowering students through digital game authorship: Enhancing concentration, critical thinking, and academic achievement. *Computers & Education, 68,* 334-344.