A Review of Empirical Studies on Educational Games: 2013-2017

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Abstract: Based on the SSCI sub-database in the Web of Science, this study selected 9 SSCI journals in the field of educational technology as sources of literature to investigate the empirical research of educational games from 2013 to 2017. We used the bibliometric method to analyze and describe the overall development of educational game research. It was found that the research hotspots mainly focus on educational game environment design, educational game effectiveness, learner motivation, and gamification teaching strategies. A content analysis framework was established based on the results of the bibliometric analysis. From the three dimensions of educational game design and development, teaching and application, and educational evaluation, a total of 113 empirical studies were analyzed panoramically. The following characteristics and trends were summarized: (1) design and development: focus on high-quality learning experiences and personalized learning; (2) games used in education: a shift from the perspective of learner characteristics to internal cognition; (3) integration of games and teaching: educational games as the main cognitive tools for the learner-centered classroom; (4) educational evaluation: the continuous exploration of gamification evaluation methods to achieve scientific, interesting, and effective assessment.

Keywords: Game-based learning; Educational games; Empirical research; Research review

1. Introduction

Since the mid-1960s, when researchers discovered the educational value of video games, various fields began to study the application of games in education. Educational game research has seen its infancy (from the mid-1960s to the end of the 1980s) and the development period (90s of the 20th century). Now it has entered a prosperous period (21st century to the present). There have been explorations of new themes and interdisciplinary cooperation studies. At present, the description of the definition of educational games is based on two perspectives: game or education. It is considered that educational games are computer system software with a certain educational purpose. They can simulate real scenes, stimulate learners' internal motivation and create learning effects in a more enjoyable experience. Since 2011, the New Media Consortium (NMC) has listed games and gamification as the key technology for the future.

In recent years, educational game research has continued to develop. This study hopes to conduct bibliometric analysis of educational game research in the last five years (2013-2017) based on the Web of Science (WOS) and conduct document content analysis of empirical research on educational games. The content is combed to grasp the current research hotspots of educational games, the characteristics of empirical research, and the direction of development, which provides practical references and empirical experiences for future research.

2. Method

2.1 Bibliometric Analysis

This study selected the Social Sciences Citation Index (SSCI) from the core collection of the Web of Science (WOS) as the source of the literature. We use the advanced search function of the WOS and

enters the query for topic search: TS= ('educational game*' OR 'learning in game*' OR 'gaming for education*' OR 'integrating the game and education*' OR 'game-based learning*' OR 'educational use of games*'), the time span was set from 2013 to 2017, and the date of search was April 14, 2018. A total of 3,902 articles were retrieved.

Considering the relevance of the field and the reference value of the literature, this study refined the documents retrieved from the initial search based on the source of the literature. We selected 9 SSCI journals[1] that are generally recognized in the field of educational technology and have a profound influence and obtained 452 articles. In this part, we used bibliometric method. HistCite and CiteSpace were used as research tools to perform quantitative analysis and co-word analysis on 452 refined documents. The basic information of the literature was described, positioning of the top ten high-impact literatures, capturing current research hotspots to understand the overall development of educational game research from 2013 to 2017, and establishing the content analysis framework of this article.

2.2 Document content analysis

Based on the above search results, we selected 160 empirical research literatures according to the relevance of the content of the articles (titles, abstracts, keywords) and educational games, as well as the screening of educational game theoretical research literatures. On the basis of reading through the articles, 113 documents were finally determined. Based on the content analysis framework from the bibliometric analysis, the content analysis method was used for the panoply analysis to obtain the characteristics and development direction of the current empirical research of educational games.

3. Results

3.1 Analysis of Educational Game Research

The HistCite and CiteSpace were used to analyze the 452 literatures. Through the analysis of the literature's time, country (region), source journals, keywords, etc., this paper reviewed the development of educational game research in the past five years.

3.1.1 Time distribution

From Figure 1 we can see that the annual output of the literature has been maintained at around 90 articles per year, of which the number of articles in 2016 has reached 102, indicating that the educational game research is in a period of stable development and gradually occupied a place in the field of educational technology.
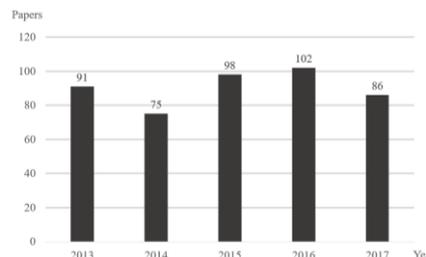
Figure 1. Time distribution of educational game research literature

3.1.2 Country(Region) distribution

The results showed that 452 documents were distributed in 48 countries (regions). According to the number of documents of each country (region), the country (region) distribution presents two

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leading positions in Taiwan and the United States. Taiwan has 138 articles ranked first, followed by the United States (111 articles).

In general, the higher the value of TLCS/N, the greater the influence of the region/country in the research field. Taiwan and the United States are still at the leading position in the TLCS/N. Although Spain and the United Kingdom are not dominant in number, their TLCS/N values have reached 1.542 and 0.905, which has a certain influence.
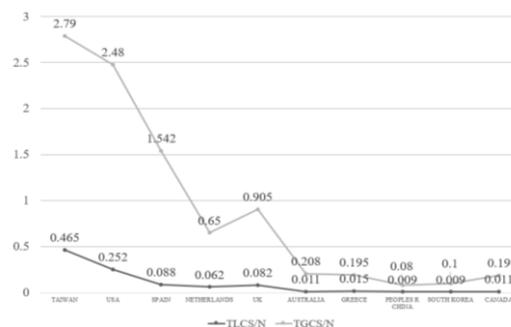
Figure 2. Top 10 Countries in the Number of Articles

3.1.3 High-impact research

The articles were ranked according to the LCS value (Table 1). The source journals of the top 10 documents were *Computers & Education*. Among the 10 high-impact researches, 9 articles are empirical research articles, of which 7 articles are based on the effects of educational games (Erhel S & Jamet E, 2013; Sung HY & Hwang GJ, 2013; Dominguez A, Et al., 2013; Hwang GJ, et al., 2013; Barzilai S&Blau I, 2014; Giannakos MN, 2013; Hwang GJ, 2015), 1 literature mainly discusses the combination of educational games and classroom teaching in mathematics, game production as learning content, innovatively implemented interdisciplinary teaching (Ke FF, 2014), and another article carried out a survey of the acceptance of secondary school teachers to educational games (Bourgonjon J, 2013). In addition, there is one more review study (Wouters P & van Oostendorp H, 2013).

Table 1

Top 10 high-impact documents of LCS

Rank	Title	Author	Journal	Year	LCS	GCS
1	Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness	Erhel S, Jamet E	*Computers & Education*	2013	27	85
2	A collaborative game-based learning approach to improving students' learning performance in science courses	Sung HY, Hwang GJ	*Computers & Education*	2013	26	107
3	Gamifying learning experiences: Practical implications and outcomes	Dominguez A, Saenz-de-Navarrete J, et al.	*Computers & Education*	2013	18	245
4	A concept map-embedded educational computer game for improving students' learning performance in natural science courses	Hwang GJ, Yang LH, Wang SY	*Computers & Education*	2013	18	75
5	A meta-analytic review of the role of instructional support in game-based learning	Wouters P, van Oostendorp H	*Computers & Education*	2013	13	67
6	An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing	Ke FF	*Computers & Education*	2014	10	43
7	Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences	Barzilai S, Blau I	*Computers & Education*	2014	9	51
8	Enjoy and learn with educational games: Examining factors affecting learning performance	Giannakos MN	*Computers & Education*	2013	8	39
9	A contextual game-based learning approach to improving students' inquiry-based learning performance in social studies courses	Hwang GJ, Chiu LY, Chen CH	*Computers & Education*	2015	8	30
10	Acceptance of game-based learning by secondary school teachers	Bourgonjon J, De Grove F, et al.	*Computers & Education*	2013	7	56

3.1.4 Research hotspot analysis

Key words co-occurrence of 452 literature data were analyzed using CiteSpace software. The threshold was set as the first 50 high-frequency keywords for each time slice. A total of 147 keyword nodes and 672 connections were obtained. In the visual display, keywords from the literature such as 'educational game', 'game-based learning', 'education', and 'game' are excluded, and the knowledge map is shown in Fig.3. Selecting the key words in the top 10 of the betweeness centrality (Table 2), combined with the frequency analysis, we can see that the current education game researches focus mainly on educational game environment design, educational game effectiveness, learner motivation, gamification teaching strategies, etc.

Figure 3. Key words knowledge map of educational game research

Table 2

Top 10 Keywords

Rank	Keyword	Mediator	Frequency
1	environment	0.16	69
2	performance	0.10	82
3	student	0.09	81
4	design	0.07	71
5	motivation	0.06	85
6	strategy	0.06	16
7	interactive learning environment	0.05	51
8	impact	0.05	46
9	achievement	0.05	36

For keywords have high frequency such as environment, performance, design and keywords that have high centrality such as strategy and achievement, we analyzed the knowledge maps (Figure 4). At present, the main contents of educational game research are four aspects of educational game design and development, application effects, teaching strategies and educational evaluation.

Figure 4. Keyword knowledge map (part)

Based on what have been discussed above, combing 113 empirical studies, the content analysis framework for this article was established (Figure 5). We believe that both application effect research and teaching fusion research belong to the teaching and application research of educational games and therefore we can obtain three main analytic dimensions including design and development, teaching and application, and education assessment.
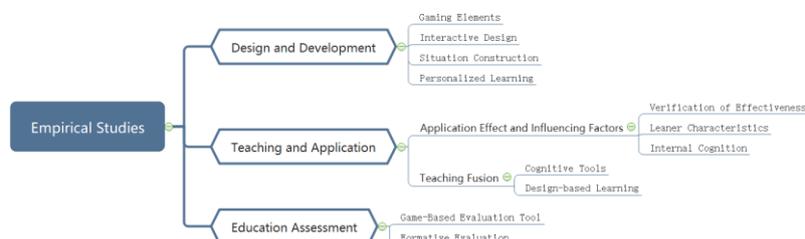
Figure 5. Analysis framework for empirical research content of educational games

3.2 Review of Empirical Research

3.2.1 Design and Development: Focus on high-quality learning experience and personalized learning

3.2.1.1. Design gaming elements and interactions to improve students' motivation

Educational games can stimulate students' motivation and interest by creating learning situations for learners. Many empirical studies (Malouf, 1988; Chile& Rosas, 2003; Hakan Tuzun, 2004) have proved that the game has a promoting effect on motivation. In the past five years, researchers have more in-depth research and discussion on how to design gaming elements and interactions to stimulate motivators more effectively and thus promote learning outcomes.

Vandercruysse et al. (2013) added the gaming element 'competition' to an educational game for business English conversation skills to explore whether the gaming elements 'competition' is related to students' motivation, learning outcomes, and perceptions. A two-factor experiment (Table 3) was designed. As educational games are a complex system, empirical research often uses single-factor experiments to discusses the effects of a certain variable separately. There are many interactive factors in the actual application environment. The two-factor experiment provides a more comprehensive discussion of the complex learning process.

Table 3

Two-factor experiment

Instruction	Competitive	Non competitive
Game environment purpose = leisure	Competitive game environment	Non-competitive game environment
Learning environment purpose = learning	Competitive learning environment	Non-competitive learning environment

There is also another discussion about the effect of games on the students' motivation. Researchers such as Lepper believe that external rewards or excessive use of external rewards have a negative impact on learners' intrinsic motivation or interest. Filsecker & Hickey (2014) investigated the impact of external rewards on the motivation of primary school students playing educational games. The results show that the addition of external rewards did not weaken students' motivation. Therefore, the negative impact of using external rewards can be solved in the new generation of learning environments with rich feedback.

In addition to the influence of game elements on learning, feedback is the most important part of the interaction between students and games. More and more scholars have begun to pay attention to the design of feedback mechanism. Guo & Goh (2016) aimed to explore the impact of

agents' emotional feedback on learning effectiveness, motivation, and fun. Adams & Clark (2014) aimed to study the impact of explanatory feedback in educational games on learning.

3.2.1.2. *Effective use of technologies such as 3D and AR to enhance game immersion*

Educational games can construct actual learning situations and achieve meaningful learning in the process of interaction between students and games. The closer the situation is to the real environment, the easier it is for students to transfer and use knowledge. In order to provide students with a more realistic interactive environment and a better learning experience, technologies such as 3D and AR have gradually begun to be widely used in the construction of immersive virtual environments.

3D environment is suitable for knowledge that is not easily taught by ordinary teaching methods or requires a high-simulation teaching environment. Maratou et al. (2016) developed a software project management (SPM) role-playing game based on a 3D online multi-user virtual world. The game simulates the situation of a company in real life and promotes the collaboration of students.

AR can help learners to connect the things they observe in the real world with relevant knowledge and realize the connection between knowledge and situation. Hwang et al. (2016) combined AR and competition to develop an ecology educational game (Figure 6) and proposed a competitive approach to support AR-based learning activities.

Figure 6. Ecology educational game

Researchers have not only considered the design of educational games from the perspective of game elements, but have started from improving the overall learning experience, enhancing the immersion of the game.

3.2.1.3. *Application of adaptive technology and data mining to provide a personalized learning experience*

Different learner has diverse ways of learning and information processing. Each learner's initial level and learning progress are also different. Educational games, as an increasingly popular learning method, also pay attention to the learner's personalized learning experience.

Due to the budget and versatility of the game, adaptive game systems are the direction that scholars actively explore. Soflano et al. (2015) developed a self-adaptive game for SQL based on learning style that can dynamically and continuously adjust the content presentation based on the learner's interaction with the game. Torrente et al. (2015) focused on special groups and developed a (semi) adaptive education game named My First Day at Work. The game configures the user interface through the initial role selection, including the role of the blind person, the role with the wheelchair, the hearing-impaired person, and the person who has no disability.

Using data mining techniques to analyze the game data can provide reference for improving the learning process, providing learning support and personalized learning experience. To explore the relationship between tool use, game selection, and task completion in the game, Cheng et al. (2017) collected back-end data from genetics games for high school students and analyzed the data using data mining techniques such as classification trees. Khenissi et al. (2017) measured learner's working memory capacity (WMC) based on fuzzy logic methods and game data.

In summary, researches of educational game design focus on providing learners with a quality learning experience. The main content includes gaming elements, interactions, environmental design and personalized learning. Many emerging technologies are constantly being incorporated into educational game design and development. Adaptive and data mining techniques are used to more effectively provide learners with learning content and support.

3.2.2 Games applied to education and teaching: From the perspective of learner characteristics to internal cognition

3.2.2.1. New perspective study, learner's flow experience and cognitive processing

With the continuous deepened empirical research on educational games, researchers not only stop at the exploration of learners' performance and characteristics, but also hope to understand the internal cognitive mechanisms of learners. New perspectives on cognitive processing and the learner flow experience has emerged. Lee & Heeter (2017) analyzes the cognitive process of players playing educational games and explores the effects of working memory skills and game skills on the player's attention and content comprehension.

Bressler (2013) used a mobile AR game to study the influencing factors of the learner's flow experience. The result shows that gender and subject interests are not important predictors of streaming experience, but game attitudes can predict 23% of flow experience differences and have a positive impact on learner flow experience. Cheng et al. (2015) further illustrated the hierarchical structure of the educational game flow experience, arguing that game immersions are divided into three phases—participation, concentration, and total immersion. From these three dimensions, the game immersion questionnaire (GIO) innovation scale was developed to measure learner's flow experience.

The above two studies have adopted scales for the measurement of player flow experience. We believe that this self-reporting method is lagging and subjective. In order to enhance the scientificity of researches, we can use the eye tracker or the game backstage to collect objective data.

3.2.2.2. New Direction of applications: Gamification

Compared to complex and costly educational games, using gaming elements and mechanics in non-game environments for a light gamification design can easily provide students with a gaming experience that is highly portable and reduces technical threshold for teachers and students. Based on the Blackboard platform, Domínguez and de-Marcos et al. (2013, 2014) integrated game elements such as challenges, badges, and leaderboards, to design and develop a gamification plugin that includes 9 challenge activities and 36 achievements. Wang (2015) integrates gamification elements such as competition, points, and leaderboards into the classroom interaction system "Kahoot!".

The gamification element design is a new direction. It has the advantages of low threshold, low cost, and universal adaptability. It is suitable for classroom teacher-student interaction, after-school exercises, and groups' tasks and other teaching activities.

Learning is a process of change that takes place within an individual. The shift from the perspective of learner characteristics to internal cognition in the empirical research of educational games helps us to combine the previous research results with the results of learning sciences and establish a link between learner performance and internal cognitive processes.

3.2.3 Game and Teaching Integration: Games as the main cognitive tool to realize the learner-centered classroom

Understanding of educational games has gone from a knowledge container to a knowledge construction tool. Nowadays, students no longer interact with teachers. Instead, they interact with educational games, independently explore and discover, and as a result, learner-centered classroom is achieved. Researchers explored the teaching strategies of teachers as mentors.

Ke (2014) designed a course that integrates computer programming, mathematics, and game production. In this course, 64 middle school students were randomly allocated to 10 groups based on Scratch for the design and development of mathematical games.

When it comes to the teaching in the classroom, game design is used as a learning method. Learners can independently design and develop educational games related to subject content. This

not only enhances learners' programming skills, subject knowledge, and learning attitude, but also fosters creativity. And this is also a new way for cross-curricular curriculum design.

3.2.4 Education Assessment: Constant exploration of gamification evaluation methods to achieve scientific, interesting, and effective assessment

Education evaluation is the premise for making scientific teaching decisions. As a potential educational reform force, educational games are used to explore scientific and effective evaluation methods with the characteristics of promoting learning motivation and participation.

Huang (2013) and others centered around the design and the development of game evaluation tools, embed diagnostic feedback that can identify learner error types and give targeted guidance into math game assessment tools.

In addition, Mavridis et al. (2017) developed a teacher-configurable mathematics evaluation game (Figure 7). Teachers do not need to have any programming skills to modify the game's parameters through the manager interface and change the content of the game.

Figure 7. the gaming environment(a) and the administration panel of the game(b)

In recent years, education evaluation research has a leap of the quantity and quality. From the quantitative point of view, more and more researches have been conducted to explore gamification evaluation methods. From the qualitative point of view, educational game evaluation research no longer stays in the summative evaluation, it began to focus on data-based formative evaluation, gamification elements used in assessment and the design and development of educational game assessment tool.

4. Discussion and Conclusion

We use the Social Science Citation Index (SSCI) in the WOS database as the source of literature to sort out the overall development of educational game research in the past five years. It is found that the current educational game researches mainly focus on educational game environment design, educational game effectiveness, motivation and game-based teaching strategies. We investigated the empirical research literature on educational games from 2013 to 2017 and found the following characteristics and trends.

First of all, educational game design and development researches focus on providing learners with a quality learning experience and personalized learning. Researchers have designed game elements, interactions, environments and integrated technologies such as 3D, AR to enhance students' immersion and maximize educational games' potential to stimulate learning motivation. Based on the self-adaptation and learning analysis techniques, personalized learning is put into practice.

Secondly, the perspective of games application research changed from learner characteristics to internal cognition. Based on the research of learning sciences, the relationship between learner performance and internal cognitive processes is established, and the learning process is deeply interpreted. Besides, educational game plug-ins became a new direction of application.

Thirdly, in terms of the game and teaching integration, games are used as the main cognitive tools to realize a learner-centered classroom. Educational games promote learners' active learning and meaning construction. Teachers provide learners with teaching aids and design reflection and summarization activities. The classroom with educational games truly focuses on learners.

Fourthly, researchers continuously explore game-based evaluation methods to achieve scientific, interesting, and effective assessments. Related research has gradually formed a branch of educational game research.

According to the review of educational game empirical study, we also got many inspirations.

In research methods, educational game research mainly adopts mixed research methods, which can break through the limitations of a single research method. Quantitative research methods help researchers to grasp the objective laws of things through the collection and analysis of objective data, which have high reliability and accuracy. Qualitative research methods can build interpretative understanding of research problems through interviews and observations. The fusion of the two methods can not only support each other, but also establish a multi-party interpretation of the problem and form a more three-dimensional understanding.

In game design, the design and development of educational games should be viewed in terms of systemic thinking to establish an effective learning environment. We should comprehensively consider the linkage between the gaming elements. With the advancement of technology, VR and other technologies also have enormous potential for enhancing game immersion. Educational games are expected to make students indulge in learning.

On the theoretical basis, exploring the cognitive laws of education and the process of learning is the basis. Researchers must develop educational game research with the learning sciences perspective. It is not only the use of learning sciences research results to interpret the results of educational research, but the integration of learning sciences and education from all aspects of the entire research process. For example, we can design and develop educational games based on learning sciences.

In technology applications, big data technology is the premise for personalized learning. We should enhance the design of data collection points and obtain more real-time and objective process data. Big data and learning analysis can help understand and evaluate learners' learning processes more comprehensively and provide targeted support for learners.

For future work, we would like to include more literatures in other databases.

Acknowledgements

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