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Analytics of motivational factors of educational video games: LDA topic modeling and the 6 C's learning motivation model

Yitong Chen[1] · **Zerong Xie**[1] · **Dickson K.W. Chiu**[1]

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Abstract
This research studies the motivational factors used in educational video games through the lens of 6 C's learning motivation model with text mining of the players' reviews and comments. This research seeks to offer insight for game producers and educational institutions to investigate the effectiveness of these motivators for increasing player motivations and thus improving the quality of learning. Sentiment analysis and LDA topic modeling were used to analyze reviews of five selected video games on the Steam platform. The 6 C's Learning Motivation Model guided text mining to analyze the motivational factors used in the games and how they contribute to user learning. The effectiveness of these motivational factors was discussed in conjunction with categorized text mining. Results show that the major motivation factors of educational games are 'construction meaning', 'challenge', and 'control' in the 6 C's learning motivation model. Among them, users focus on whether the game's content meets their interests and the construction of the educational meaning of the game. The advantage of control, a high degree of motivational factor in video games, may turn out to be a factor that leads to user churning when the game is not interesting or attractive enough. Previous educational game research seldom involved a large sample size for generalizable findings. In addition, this research extends the application of the 6 C's learning motivation model to the digital educational gaming arena, providing a novel player-centric perspective. Based on the results, we provide recommendations and design considerations for educational game developers to enhance players' experience and motivations.

Keywords Educational video games · Game-based education · 6 C's learning motivation model · Text mining · LDA topic modeling · Sentiment analysis · Learning motivation

Extended author information available on the last page of the article

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1 Introduction

Educational games have become increasingly important to engage learners (Bulut et al., 2022; Castronovo et al., 2022; Khan et al., 2022; Shi et al., 2022; Xiong et al., 2022; Yu et al., 2022). The growth of the video game industry has facilitated a growing number of organizations and video game producers to turn their attention to the production of video games for educational purposes (Cole et al., 2023; Martinez et al., 2022; Palma-Ruiz et al., 2022). For example, Amazon released the AWS Cloud Quest Game to help users learn cloud skills and make learning more fun (Amazon, 2022).

Multiple studies have demonstrated the effectiveness of using computers and video games as educational media for improving motivation and the quality of learning experiences (Yu et al., 2022). In contrast to the close connection between teacher and student in game-based education (Jääskä & Aaltonen, 2022), video game users often play educational video games without the involvement of a teacher to monitor their learning. Regular players are generally motivated by having "fun" while playing video games (Martucci et al., 2023). Therefore, educational video games often need to be fun to maintain customer motivation while still being educational. If the game is not sufficiently "fun" or does not provide enough motivation, user engagement in the game will be compromised, especially if it is unsupervised (Banyte & Gadeikiene, 2015). Thus, the motivational factors embedded in educational games are crucial for engaging users and their learning results (Martucci et al., 2023).

Moreover, due to the lack of supervisor involvement, learning quality is usually assessed through game achievements and review feedback (Smiderle et al., 2020). Since users are the direct recipients of educational video games, both text mining and sentiment analysis of the information contained in user reviews are effective research methods. Therefore, this research focuses on the motivational factors in educational video games and their effectiveness by mining the reviews of educational video games, guided by the 6 C's learning motivation model, to make relevant suggestions. Our findings provide a reference for researchers, game producers, and educational institutions to help them better understand the motivational factors in educational games and user feedback on these motivational factors for developing this new emerging cross-displinary field. Based on the diversified development and fierce competition in education, educational games also face many opportunities and challenges for development (Oyelere et al., 2020) and sustainability (Li et al., 2024; Yao et al., 2024). Therefore, this research helps understand user feedback, which is crucial to the development of the field.

Thus, this research reviews programming-based educational video games on the world's leading gaming forums. The forums and games are selected based on the number of users and review data. The Steam platform is one of the personal-computer game platforms with the largest number of games and the widest audience on the whole network, and many of its games have educational purposes or implications (Moro et al., 2022). Therefore, this research selects games on Steam as the research object and analyzes the reviews of educational video games in the programming category, which is one of the educational video games with the broadest audience at this stage and has a separate partition on the Steam platform. Since this research focuses

on user and follower sentiment towards educational video games in the whole programming category and needs to ensure the quantity and accessibility of data, the selection criteria are game popularity and number of reviews. This research selects five programming educational video games with more than 2,000 reviews on the Steam platform, including "Hacknet," "Human Resource Machine," "SHENZHEN I/O," "SpaceChem," and "while True: learn()."

Many well-known online gaming forums worldwide generally provide real-time gaming information and discussion boards for gamers. These online forums include Steam Community, PC Gamer, NeoGAF, VGR, etc. In addition, social media such as Twitter and Instagram also include many game discussions. Due to the need to obtain game reviews from players with experience with them, to reduce the influence of factors such as public impressions, advertisements, and irrelevant information on the quality of the reviews, and to ensure the quantity and accessibility of the data, the scope of forum selection in this research only includes professional game forums. Since the games selected are published on the Steam platform and the Steam Community, as the forum of the Steam platform itself, has many accessible reviews, this research finally chooses it as the forum for review acquisition.

This social media analytics research examines the user reviews of five programming educational video games in the Steam Community, uncovers keywords in the reviews, and discusses the motivational factors of these games based on the 6 C model of learning motivation. Then, this research analyzes the effectiveness of these motivational factors based on sentiment analysis and makes relevant recommendations. The findings serve as a reference for researchers and developers in educational games to improve the application of motivational factors, thus enhancing the user experience and increasing the value of future educational games. In addition, this application of text mining and sentiment analysis to game reviews related to educational games can lay the foundation for future research to investigate users' perceptions of educational games and promote sustainable development of educational video games.

2 Literature review

2.1 Education, games, and educational video games

Traditional education is rooted in schools and educational institutions (Dewey, 1916). However, in recent years, there has been a shift towards innovative pedagogical practices such as online learning, gamification, and many other forms due to technological advancement and ubiquitous Internet connections (Yip et al., 2021; Zhang et al., 2021). Games are activities with structured play, competition, and rules (Salen & Zimmerman, 2010), typically recognized as voluntary participation and fun (Reid, 2012; Juul, 2016). Video games utilize electronic technologies, such as computers or consoles, to provide digital gaming experiences (Consalvo, 2022). Educational games are designed for teaching and learning, combining gameplay and educational content to facilitate knowledge acquisition, skill development, etc. (Gee, 2003; Kebritchi et al., 2010).

Several studies have shown that using computers and video games as educational media is highly effective in improving motivation and the quality of the learning experience (Yu et al., 2023). The previous section discussed the benefits of video games for perception, attention, and cognition (Donohue et al., 2010), and the possible mechanistic basis for their inclusion is "learning to learn." According to Yu et al. (2023), Gamified Online Learning (GOL) has a moderate positive impact on learning, especially improving grades. Educational video games, exemplified by Minecraftedu, provide a fun and popular environment that promotes students' design skills without other tools (Tonbuloğlu, 2023).

Researchers have begun to focus on combining educational and video games to make the learning process more interesting while avoiding, as much as possible, the genre conflicts that exist in some students' expectations of playing computer games (Hew et al., 2016). As a result, serious educational games have become a more and more popular topic in recent years (Annetta, 2010). Their primary purpose is to have fun plus train skills and abilities in other areas (Noemí et al., 2014). As a result, research has gradually shifted from whether games have an educational potential to the need to integrate games into the complexity of the curriculum or to examine the quality of the learning process (Squire, 2005).

Public attitudes toward the adoption of educational video games show a wide variation. While society is prejudiced against video games, some game advocates hope to augment traditional schooling with computer game-based educational activities (Mayer, 2016). In response to some populist rhetoric condemning video games, Whitton (2015) argues that they can undermine "the acceptability of games and limit critical analysis of their effectiveness" as a pedagogical tool. The addictive nature and limitations of games do not limit their benefits in other ways. Despite various limitations, many scholars have recently supported video games in educational settings (Coleman et al., 2019; Dahalan et al., 2023; Kaimara et al., 2022).

2.2 Attractiveness and motivational factors of games

Przybylski et al. (2010) showed that the attractiveness and motivation of video games are generally based on "their potential to satisfy basic psychological needs of competence, autonomy, and relatedness," rooted in self-determination theory (Leitão et al., 2022). Reid (2012) further summarized the mindstream experience theory and attribution theory explanations of play motivation by discussing intrinsic (e.g., fun-seeking) and extrinsic (e.g., problem avoidance) motivations for play. For example, students with intrinsic motivation tend to use the coding game more actively (Zhang, Wong & Chan, 2023). Reid (2012) argues that the risk of addiction-related behaviors increases if the players' primary motivation is avoidance or escape from other activities. The tendency of preschoolers to become addicted to digital games has also been found to be associated with negative mother-child relationships (Emiroğlu İlvan & Ceylan, 2023), reflecting extrinsic avoidance motives. This is similar to the findings of Wood (2007) discussed earlier, implying that addictive behaviors are correlated with motivational factors.

Furthermore, even though different types of gamers have different motivations (Westwood & Griffiths, 2010), the design of video game achievements significantly

increases player performance and motivation (Blair, 2011). These designs affect high, middle, and low-achieving students differently, with gamification having a greater impact on low-achieving students (Kam & Umar, 2022). Besides, some problematic video games boost player motivation by exploiting realistic needs and frustration (Mills et al., 2017). Therefore, a discussion on the rationality of game motivation factors is necessary. Finally, since user motivation to play games directly affects their engagement with video games (Banyte & Gadeikiene, 2015), studying motivational factors is crucial for user attraction and stickiness.

2.3 6 C's learning motivation model and motivational factors in education

Turner and Paris' (1995) 6 C's Learning Motivation framework describes motivational factors in the educational process, which identifies six factors to improve learning motivation: choice, challenge, control, collaboration, constructing meaning, and consequences. Choice refers to providing learners with options in course design that allow them to choose more interesting topics, and learners make more effort to learn the content of topics they are interested in and curious about (Chan & Chiu, 2024; Lam et al., 2023). Challenge refers to designing appropriate challenges for courses and assignments. Challenges that are too difficult may cause students to become frustrated, and challenges that are too low may bore students and make them disengage. Control refers to appropriately allowing learners to control their learning planning and progress. Too much control may confuse them, and too little may make them lack independence. Collaboration refers to setting up cooperation appropriately. Lake (2017) argues that group work in online courses can be challenging due to technological requirements, time zone differences, and other reasons, which technological advancements have recently streamlined (Dong et al., 2021). Constructing meaning refers to setting up significance in the course design and clarifying the learning objectives associated with assignments and instructional materials. Consequences refer to making learners aware of the consequences and effects of their actions. For example, not doing homework may lead to failure, and studying hard may reap higher grades and appreciation from others.

Several studies have underscored the vital role of the factors in 6 C's Learning Motivation Model in promoting learner engagement and persistence in different learning situations (Laine & Lindberg, 2020). For example, previous research demonstrates that challenging learning content effectively stimulates learners' intrinsic motivation (Kaya & Ercag, 2023). Reeve (2009) emphasized the importance of providing learners with a sense of control as this enhances their intrinsic motivation and self-regulation. Collaboration and competition in the learning environment promote social interaction, goal setting, and a sense of accomplishment, effectively promoting deeper learner engagement in learning (Johnson & Johnson, 1989). Also, recognizing and giving feedback on learners' progress can greatly enhance their motivation and lead to deeper engagement in learning (Deci & Ryan, 2000). Recently, Chan and Chiu (2024) have applied the 6 C's model to a sustainable reading promotion curriculum with technology tools for disadvantaged communities in rural China.

The 6 C's Learning Motivation Model motivates learners by incorporating six motivational factors into the curriculum design, aligning with the motivational fac-

tors mentioned in the video games. For example, the design of achievements in video games mentioned by Blair (2011) has the same principles as the factor "Consequences" in 6 C's Motivation. The intrinsic motivation of gamers to pursue fun (Reid, 2012) parallels the idea that learners will spend more time learning about topics that interest them (Lam et al., 2023; Leung et al., 2023). Therefore, whether educational video games, as a combination of games and education, contain motivational factors that can effectively promote user learning is a more refined direction worth investigating.

2.4 Text mining in the field of education and LDA topic modeling

Text mining (TM) is the process of extracting information and meaning from semantically rich, unstructured text, which is especially suitable for social media with increasingly useful information (Li et al., 2023a, b; Liu et al., 2023). Latent Dirichlet allocation (LDA) is one of the most popular text mining methods, which is a probabilistic model for generating discrete sets of data (Jelodar et al., 2018), has been widely used to identify potential topics in text corpora automatically (Blei et al., 2002). Maier et al. (2018) discuss four main challenges affecting LDA models' accuracy and validity: proper preprocessing of text, appropriate selection of model parameters, assessment of model reliability, and effective interpretation of the topic generation process.

Previous studies utilizing these methods have followed a systematic methodology. First, researchers collect a variety of educational texts, such as academic papers, textbooks, or online discussions, to create a representative corpus. Then, the texts are preprocessed, including tokenization and removal of text noise and stop words, to prepare the data for analysis (Blei et al., 2003). Next, LDA topic modeling is applied to estimate the distribution of topics, identify key terms associated with each topic, and assign text to relevant topics (Blei et al., 2003).

Text mining is widely used in education as educational approaches are diversifying. For example, Martí-Parreño et al. (2016) analyzed past studies on the use of games in education by using text-mining techniques to provide researchers with useful information on publishing trends, research directions, etc. Pacella and Marocco (2022) used text mining techniques to analyze information in the texts of users' conversations with virtual characters in negotiation skills educational games. Researchers and teachers extract information from online resources, posts, and comments by designing models that mine student feedback to improve online learning platforms (Almatrafi et al., 2018; Li et al., 2023a, b; Xie et al., 2023a, b).

2.5 Sentiment analysis and social media/forums

Sentiment analysis computationally deals with the opinion, sentiment, and subjectivity of the text (Medhat, 2014). It is widely used to analyze a large number of personalized comments present on social media, blogs, and other platforms (Devika et al., 2016). Basic sentiment extractors classify texts into those with positive or negative (or sometimes neutral) sentiments (Thompson et al., 2017). With the rise of e-learning, sentiment analysis is increasingly used to analyze students' opinions so

that educators can better understand their thoughts and take more effective and targeted actions (Mite-Baidal et al., 2018; Li et al., 2023a, b). Rani and Kumar (2017) analyzed student comments from course surveys and online resources to determine the emotions expressed in texts, emotional polarity, satisfaction, and dissatisfaction.

Compared to education, few studies use sentiment analysis to analyze sentiment in game-related texts, but for more diverse purposes. Stråat and Verhagen (2017) analyzed sentiment in reviews of two video games and found a high correlation between ratings of user reviews and related aspects of sentiment, while Narwal and Aggarwal (2021) used social media review data to predict addictive behavior in online games through sentiment analysis. These studies suggest that sentiment analysis for analyzing game reviews has proven meaningful. However, little research uses sentiment analysis to analyze educational video games, which can be considered a research gap.

2.6 The value and controversy of video games

According to Statista, the number of gamers worldwide is estimated to be 3 billion in 2022, and the percentage of Internet users playing video games on any device is about 81.9%. Video games have become one of the mainstream hobbies in society. According to Gandolfi et al. (2023), online gaming is a double-edged sword that can positively and negatively affect players' physical and mental health.

Several studies have shown video games beneficial in several areas. For example, action video games have perceptual, attentional, and cognitive benefits for users, while those with extensive video game experience are stronger in visual perception and multisensory processing (Donohue et al., 2010). Digital games enhance students' spatial reasoning and promote greater engagement (Yang & Chen, 2023). Several studies have found uses for video games in mental health treatment (Wilkinson et al., 2008). According to Velez et al. (2014), cooperative video games can increase players' subsequent pro-social behavior. Exercises that combine video games with traditional exercise have provided better results (Warburton et al., 2007). In addition, gaming helps to enhance personal well-being (Gandolfi et al., 2023).

However, because video games have been found to be addictive (Weinstein, 2010), public perceptions of educational video games remain controversial, even though multiple studies have shown that video games are beneficial in multiple domains (Funk & Buchman, 1995). Wood's (2007) case study argues that people's excessive video game play is not inherently addictive but may be due to "ineffective time management skills or a symptomatic response to other underlying problems" they are avoiding. This phenomenon is particularly pronounced for children; the effects diminish as they become adults. Griffiths et al. (2012) summarized the last ten years of research on video game addiction and discussed the prevailing academic view that excessive video game use has negative consequences and that most of these negative consequences result from inappropriate use. In addition, the type of video game is also related to its positive or negative effects. For example, while cooperative video games can increase users' pro-social behavior (Velez et al., 2014), video games that contain violence increase aggression and decrease pro-social behavior (Ewoldsen et al., 2012).

2.7 Research gap

Although previous studies on educational video games are mostly based on theoretical studies or surveys, studies that systematically analyze user perceptions using text mining and sentiment analysis are absent. In addition, most previous studies have focused on games designed specifically for education, and fewer studies have been conducted on educational games on specialized gaming platforms. With the diversification of education and the development of the Internet, using a quantitative approach to study users' opinions and emotional feedback on educational games is a topic worthy of further research. From the perspective of motivational factors, there have been many studies on educational motivation and video game motivation, but few explore the motivational factors of educational video games in more detail. Therefore, our research can help game designers and educational institutions better understand users' opinions, emotional feedback, and motivational factors in educational video games. The suggestions provided can help improve the design of educational video games and promote the development of educational video games. Further, it helps users understand the reasons behind the appeal of educational games and provides them with a reference for the quality of educational games. Three research questions (RQs) guide the research:

RQ1*What are the characteristics of the user reviews' sentiment of the selected educational video game?*
RQ2*How do educational video games motivate users to learn?*
RQ3*How effective are those motivational factors used in educational video games?*

3 Methodology

3.1 Methodological framework

Figure 1 shows the methodological framework of this research. First, this research used a web crawler to collect reviews from the pages of five selected games in the Steam community. These review data were then cleaned and preprocessed, including removing text noise, expanding contractions, and removing stop words. The preprocessed data were subjected to sentiment analysis for the game review data's emotional feedback and correlation factors. LDA topic modeling was used to mine the key themes in the text and link them to the factors in 6 C's learning motivation model. Subsequently, the texts were categorized according to different sentiment and recommendation categories (Recommended with positive sentiment, Not recommended with negative sentiment, and Others). This categorization facilitates further keyword and topic mining from the texts from the motivation and the de-motivation perspective. In this phase, we manually examine the reviews to synthesize the motivation and de-motivation factors. In conjunction with 6 C's learning motivation model, this

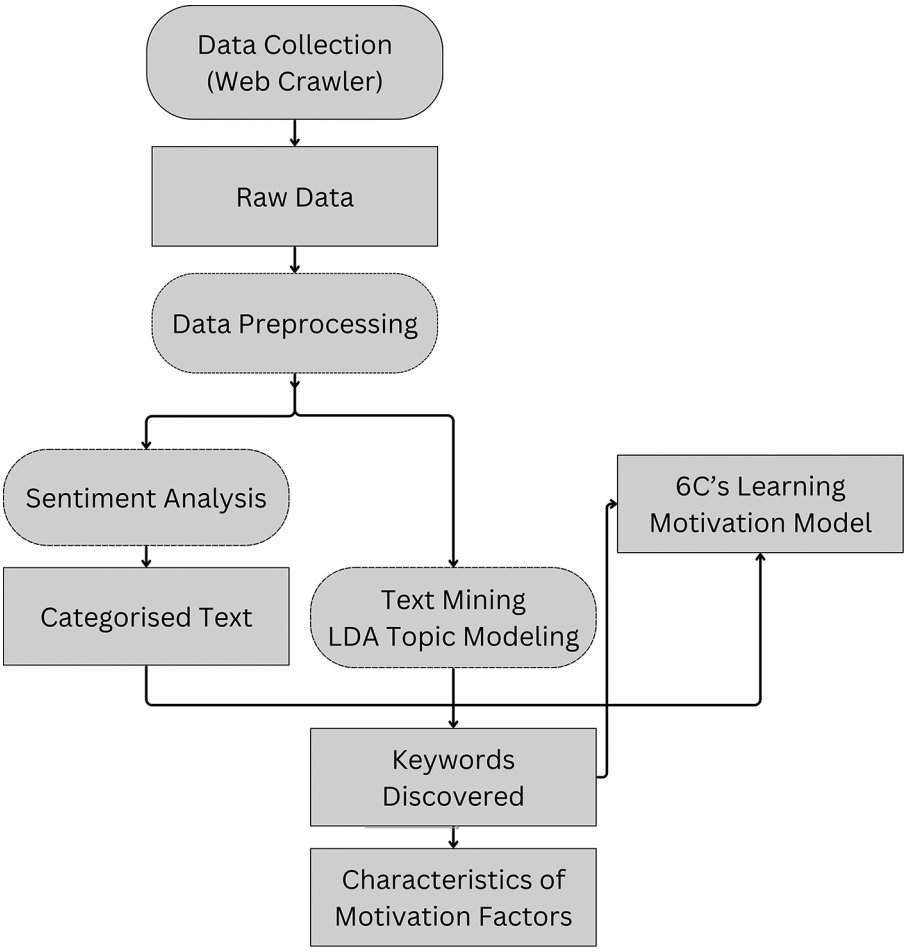

Fig. 1 Methodological framework

study discussed the association of the revealed motivational and demotivational factors by synthesizing the review comments with the identified keywords.

3.2 Data collection

This research crawled the reviews of the above five games from the Steam Community. Table 1 shows the information on the games selected. The range of reviews crawled was from January 1, 2020, to December 1, 2022. Web scraping, or web crawling, is commonly used in contemporary research to extract structured data from text (Khder, 2021).

This research used Python's Selenium library to develop a simulated web crawler for data collection tasks. The web crawler searched for posts in social media by simulating a human login and based on given keywords (Xie et al., 2020) and followed instructions to obtain specific information and relevant content, such as the user's

Table 1 Educational video game chosen for analysis

Game Name	Game ID	Release Date	Mode	Steam Rating	Genres
Hacknet	365,450	August 13, 2015	Single-player video game	9/10	Indie, Simulation
Human Recourse Machine	375,820	October 15, 2015	Single-player video game	9/10	Casual, Indie, Simulation
SHENZHEN I/O	504,210	November 18, 2016	Single-player video game	10/10	Indie, Simulation
SpaceChem	92,800	March 3, 2011	Single-player video game	10/10	Indie, Simulation
While True: learn()	619,150	January 17, 2019	Single-player video game	9/10	Indie, Simulation

screen name, comments' content, and whether or not it was recommended. Since each game has a corresponding page in the Steam Community, all the comments about that game were displayed in the comment section of that game page. As this research did not need to crawl the text by keywords from inside the massive data but could directly crawl all the comments in the corresponding comment section, we considered the keyword selection.

3.3 Data cleaning

Since reviews from the Steam Community are displayed on the corresponding game pages, the probability of crawling irrelevant information is low. However, the collected game text data may still contain problematic rows (e.g., ads, blank comments). For these problems, this research manually removed invalid data rows using Excel's filtering and sorting tools due to the small amount of data. In addition, text noise should be removed in text mining studies to facilitate the analysis results (Celardo et al., 2016).

In this research, the comments might contain a large amount of text noise, e.g., emoji codes, due to the high internet presence of the game users. These text noises were removed using Python. Sentence contractions were also expanded to minimize keyword mining bias. Removing deactivated words, i.e., those with no information, was included in data preprocessing (Gerlach et al., 2019). This research used the stopword package from the NLTK (Natural Language Toolkit, https://nltk.org/) library to remove stopwords. In addition, some other stop words, such as *like*, *bit*, *good*, and *lot*, were defined based on the output.

3.4 Sentiment analysis of game comments

This research analyzed review sentiment using the VADER (Valence Aware Dictionary and sEntiment Reasoner) lexicon method for correctly extracting sentiment features on unlabeled datasets (Marutho et al., 2022). This research used the NLTK library to download vader_lexicon for sentiment score calculation. After extracting meaningful words from the sentences, we calculated the sentiment scores and weights of these words based on the VADER Lexicon and the text's sentiment scores. This research further analyzed the comment sentiment and correlation using a correlation matrix from the perspectives of time series, comment length, and comment type.

3.5 LDA topic modeling and text mining

This research performed text mining and LDA topic modeling with TF-IDF, one of the most commonly used term weighting methods in text mining today, comprising TF (Term Frequency) and IDF (Inverse Document Frequency) according to the following formula:

$$\mathrm{tf} - \mathrm{idf}(\mathrm{t}, \mathrm{d}) = \mathrm{tf}(\mathrm{t}, \mathrm{d}) * \mathrm{idf}(\mathrm{t})$$

TF-IDF would determine the collected terms' importance and find the most important ones. Then, the six topics were generated using these terms based on LDA topic modeling.

3.6 Categorized text mining

Due to the complexity of users' emotions and attitudes, emotional feedback or whether a recommendation was made was not used to determine the effectiveness of motivational factors. This research combined these two aspects and categorized the data into three groups. Group 1 was recommended with positive or neutral sentiments (5,395 rows); Group 2 was not recommended with negative or neutral sentiments (183 rows); and Group 3 was recommended with negative sentiment or not recommended with positive sentiment, with 650 rows. Text mining was further conducted based on the categorized review with TF-IDF. Then, the top 20 frequently used words were discovered for each category.

3.7 6 C's learning motivation model

Based on the results of topic modeling and text mining, this research applied the 6 C's model of learning motivation to discuss which of the motivating factors in the model these keywords were associated with. Based on the text mining results on categorized reviews, this research further investigated which motivating factors were affected by different categories of texts, respectively, and the effectiveness of these motivating factors. Finally, relevant recommendations were provided to improve the application of motivating factors in educational video games.

4 Results and discussion

4.1 Characteristics of data collected

Table 2 shows the number of reviews collected. A total of 6228 rows of data from January 1, 2020, to December 31, 2022, were collected for this study, with 2686 rows of data from Hacknet and 1665 rows of data from While True: learn() as the main components of this dataset. The collected dataset comprised seven attributes: *user ID, profile URL, comment text, whether recommended or not, length of comment, length of play*, and *date of comment posting*. Table 3 shows the sample data from the collected dataset.

Next, the data was preprocessed, including removing text noise, expanding contractions, and removing stopwords. Figure 1 shows the word cloud produced by the top 100 frequent terms in the cleaned dataset. Table 4 shows the top 50 frequent terms in the cleaned dataset and their TF-IDF scores. *Game* has the highest importance, followed by *fun* and *puzzle*. All these words are highly correlated with the game. Results indicated that these words cover a wide range of game-related topics, including but not limited to fun, experience, meaning, difficulty, derivatives, achievement, etc., reflecting to some extent that different players have different motivations (Westwood & Griffiths, 2010).

4.2 Sentiment analysis (RQ1)

Figure 2 shows the change in the number of reviews of different sentiments between January 2020 and December 2022. Overall, all three categories of reviews showed an extensive range of fluctuations in short periods. The fluctuation cycle aligned with the discount cycle of these games on the Steam platform, meaning the number of user reviews rose significantly during the discount period. There were three peaks during this period: June 2020, November 2020, and February 2022.

The first two peeps were when the COVID-19 epidemic was severe in the United States and other English-speaking countries, the main source region for the data. The higher number of reviews in 2020 was probably related to increased leisure time due to the epidemic. Overall, positive reviews of these games showed a slow downward trend from 2020 to the first half of 2021 and then stabilized from the second half of 2021 to the end of 2022, while neutral and negative review performances were more stable during the period. In addition, the direction of fluctuation of the reviews in the three sentiment categories showed consistency, meaning the distribution of users' sentiment towards the game did not change significantly over time.

Table 2 Number of reviews from 2020.01.01 to 2022.12.31

Games	Reviews Count
Hacknet	2686
Human Resource Machine	547
SHENZHEN I/O	914
SpaceChem	416
While True: learn()	1665
Total	6228

Table 3 Sample data

Review Text	Review	Review Length (Chars)	Play Hours	Date Posted
This game is hard. 10/10. When you are done having a bad time, reactors will mean the same.	Recommended	81	61.9	18/12/2022
Just play it. I have been for maybe 10 years…	Recommended	39	115.4	16/12/2022
I love this game so much	Recommended	19	24.9	15/12/2022
It's a ZT game, of course, it's good. Maybe not the one for me, but it is still good.	Recommended	66	1.9	06/12/2022
5 Stars for this game but 2.5 stars for Zachtronics. After I got this game on IOS, they took it off the app store. I went back to play it afterward and discovered that Zachtronics couldn't be bothered to update the game to be compatible with IOS changes. It left a really bad taste in my mouth for their games.	Recommended	252	10.5	31/12/2022

Table 4 Top 50 words in the cleaned dataset

No.	Word	TF-IDF Score	No.	Word	TF-IDF Score	No.	Word	TF-IDF Score
1	game	710.24	21	concept	56.51	41	educational	39.60
2	fun	362.11	22	worth	54.01	42	music	37.25
3	puzzle	218.82	23	hard	52.11	43	dlc	36.81
4	programming	150.59	24	level	51.87	44	buy	36.13
5	play	105.90	25	easy	50.75	45	solution	35.91
6	time	97.74	26	hour	50.46	46	enjoyable	35.81
7	story	95.49	27	experience	49.55	47	language	35.19
8	learn	92.02	28	hack	47.50	48	programmer	33.72
9	machine	88.09	29	basic	45.43	49	simulator	33.36
10	interesting	76.50	30	challenge	44.79	50	difficult	32.91
11	cool	76.13	31	brain	44.59			
12	hacker	73.62	32	assembly	43.77			
13	coding	71.36	33	code	43.47			
14	challenging	69.99	34	simple	42.89			
15	work	69.22	35	enjoy	42.87			
16	cat	67.32	36	problem	42.64			
17	solitaire	66.82	37	gameplay	41.19			
18	real	66.13	38	teach	41.05			
19	command	64.29	39	people	40.07			
20	logic	59.75	40	hackerman	39.63			

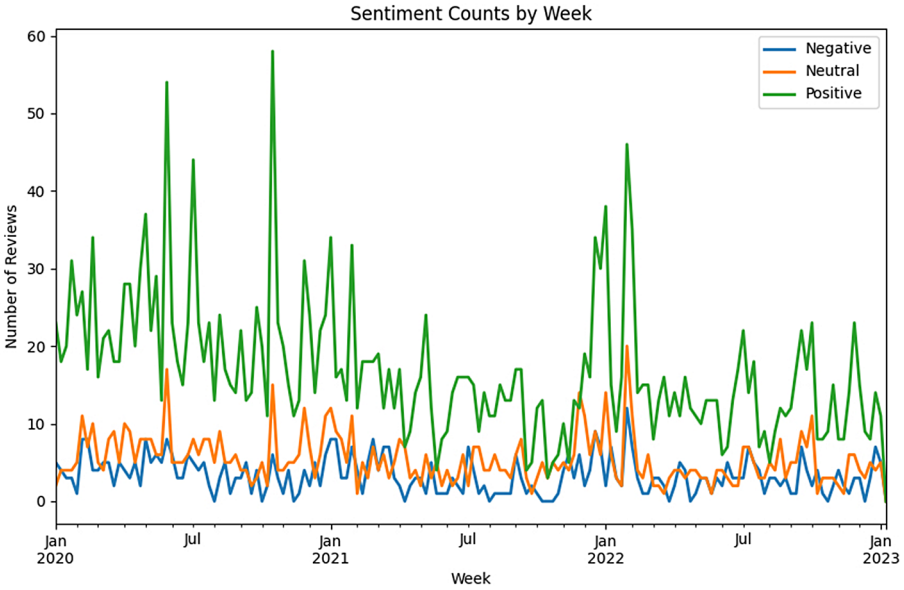

Fig. 2 Number of positive, neutral, and negative reviews by week

Table 5 Top 10 frequent words in three peaks

Peak 1	[‘game’, ‘puzzle’, ‘good’, ‘fun’, ‘machine’, ‘great’, ‘program’, ‘interesting’, ‘work’, ‘recommend’]
Peak 2	[‘game’, ‘puzzle’, ‘good’, ‘time’, ‘fun’, ‘programming’, ‘machine’, ‘work’, ‘code’, ‘enjoy’]
Peak 3	[‘game’, ‘fun’, ‘great’, ‘puzzle’, ‘time’, ‘hacker’, ‘recommend’, ‘story’, ‘command’, ‘good’]

Table 5 shows the top 10 most frequently used words in the three peaks, indicating no significant change in users’ focus on games in these peaks. Words such as *puzzle*, *fun*, *interesting*, and *work* indicated that users mainly focus on the fun and core content of the game. As time passed, the appearance of words such as “time” indicated that users focus part of their attention on the length and control of the game, which might be because, in the last two peaks, the work affected by COVID-19 gradually resumed (Huang et al., 2021, 2022, 2023), and users’ leisure time was reduced accordingly.

Figure 3 shows the sentiment distribution for different categories of reviews (recommended or not recommended), indicating that both recommended and non-recommended reviews were positively skewed and had positive means. Overall, recommended reviews had higher sentiment scores and a wider distribution of sentiment scores. Interestingly, even for reviews not recommended, the mean of the sentiment scores carried by their reviews was positive, meaning that more than half of the user reviews that did not recommend the game did not carry negative emotional feedback. In contrast, some of the comments from users who recommend the game instead carried negative emotional feedback, suggesting that whether a user recommends the game could not accurately reflect positive user sentiments.

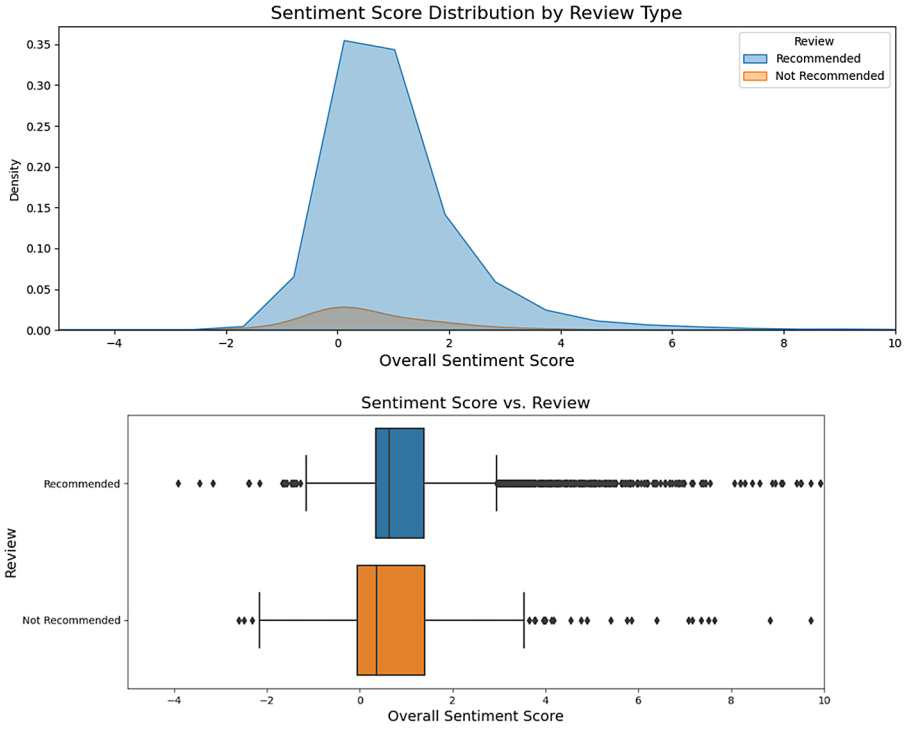

Fig. 3 Comparison between sentiment score and review type

Table 6 Review type vs. sentiment score

Game	ReviewType vs. SentimentScore (consider neutral)	ReviewType vs. SentimentScore (ignore neutral)
SpaceChem	70.91%	80.38%
While True: learn()	80.96%	88.34%
SHENZHEN I/O	75.27%	86.22%
Human Resource Machine	74.59%	84.82%
Hacknet	76.40%	90.44%
Overall	**76.93%**	**88.05%**

The consistency rate was calculated between review categories and sentiment scores to investigate their relationship more deeply. Table 6 shows the percentage where the review category (recommended or not recommended) is consistent with each game's sentiment feedback (positive, neutral, or negative). Consistency is defined as positive or neutral emotional feedback when the review category is recommended and negative or neutral emotional feedback when the review category is not recommended, and vice versa. Results showed that 76.93% of the categories in the data were congruent with the sentiment feedback when neutral sentiment was taken into account, while 88.05% of the data were congruent when neutral sentiment was ignored. In this case, *While True: learn()* and *Hacknet* had the highest probability

of consistency between the sentiment categories and the recommended categories, 80.96% and 76.40% for considering neutral and 88.34% and 90.44% for ignoring neutral, respectively. A higher percentage implied users' emotional feedback and whether to recommend were more consistent, indicating that they were more highly correlated with their emotional feedback. Conversely, it indicated some discrepancy between the user's emotional feedback and whether it was recommended, and it also considered the possibility that the emotional score was not calculated accurately.

Figure 4 is a heat map showing the correlation matrix of the four variables: recommendation type (1 for recommendation and 0 for non-recommendation), review length, play hours, and sentiment score. Among them, recommendation type negatively correlated with review length, meaning that non-recommended reviews had longer review lengths, while recommended reviews had shorter ones. This might be because non-recommended reviews tended to give more feedback and opinions.

Besides, review length and sentiment score showed a positive correlation, meaning the longer the review length, the higher the sentiment score. There would be two reasons: (1) Sentiment analysis based on the VADER lexicon approach determined that the longer the length of the text, the more words with sentiments mined, and the sentiment scores would be more extreme; or (2) sentiments might motivate users to make more expressions and feedback. Finally, no other correlations between other variables were found.

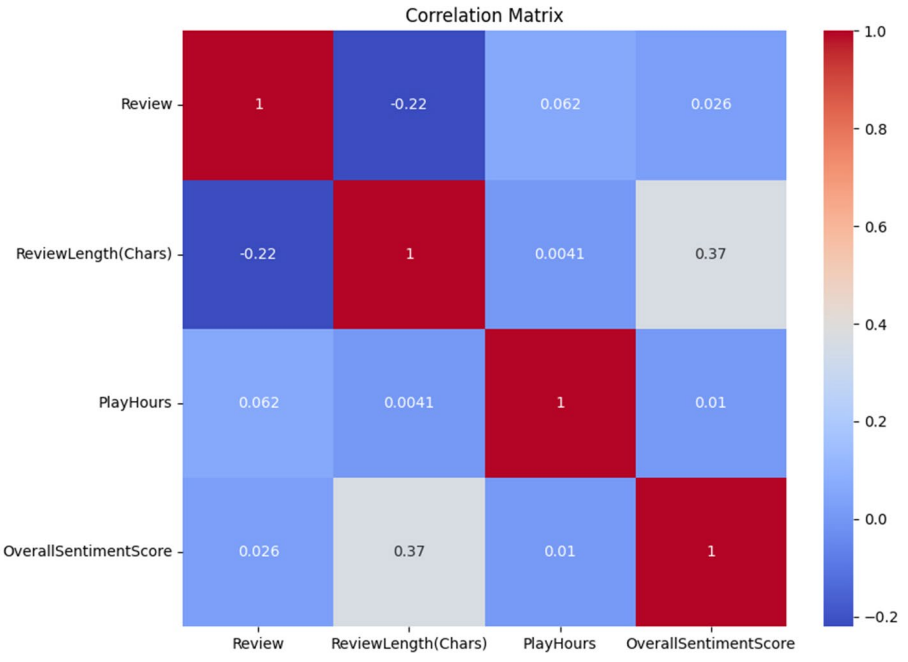

Fig. 4 Correlation matrix

4.3 LDA topic modeling (RQ2)

By observing the results and related terms of different numbers of topics and adapting the subsequent 6 C's learning motivational model, six topics were finally identified as the optimal choices. Figure 5 shows the interactive visualization of LDA topic modeling. The left side shows the distribution of topics and their correlations, while the right side shows each topic's corresponding top 30 most relevant terms. Regarding distribution, Topics 1 and 2 far exceed the others, while Topic 3 slightly overlaps with the others, and the other three topics have highly overlapping parts. This means some parts of these three topics are similar or related. Table 7 records the corresponding top-10 most relevant terms for these six topics.

All six topics covered one or more relevant dimensions of programming educational games. Topic 1 covered many computer and programming terms such as *file, server*, etc., reflecting some of the specialized technical discussions involved in user discussions. Thus, the samples were randomly checked under this topic to further analyze whether these keywords were related to the game content. Results showed these keywords were mainly associated with the game's storyline or setting and contained some non-content technical discussions, e.g., how a file should be saved.

These keywords reflected some of the knowledge and value that users gained while participating in the game from the side. In addition, some samples under the topic showed that some users were asked by their schools to play the game as an assignment, involving the further application of educational video games in teaching and learning environments. Topic 2 reflected users' thoughts on real-world game-related factors like "money" and "life." Upon random checking of the sample, results indicated that money mostly appeared alongside worth, indicating that users thought

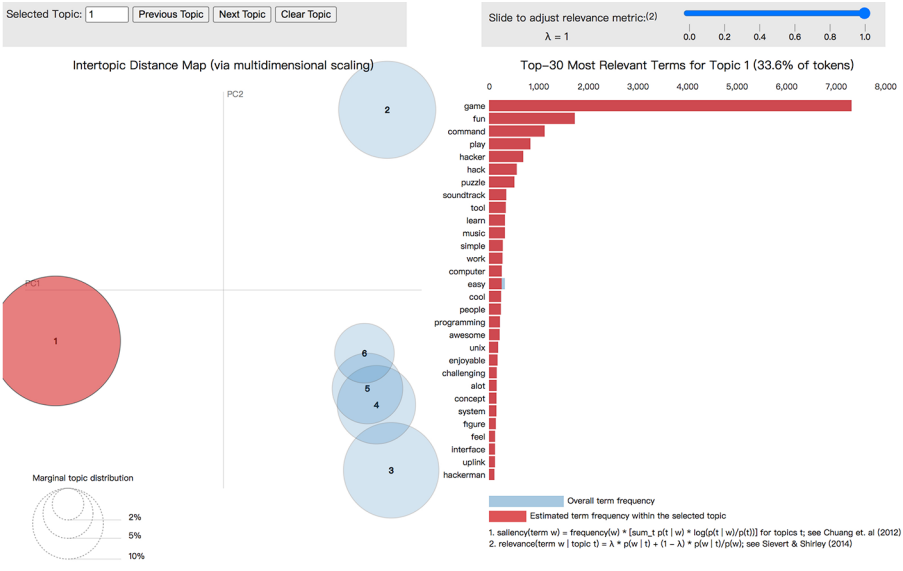

Fig. 5 Interactive topic visualization

Table 7 Discovered topics

	Topic	Words
1	Technology	0.028*"file" + 0.020*"server" + 0.019*"terminal" + 0.012*"text" + 0.012*"simulator" + 0.011*"job" + 0.011*"achievement" + 0.011*"log" + 0.010*"network" + 0.009*"secret"
2	Reality	0.026*"realistic" + 0.023*"life" + 0.021*"bug" + 0.020*"money" + 0.017*"open" + 0.017*"idea" + 0.014*"graphic" + 0.012*"average" + 0.012*"fast" + 0.012*"beautiful"
3	Fun & meaning	0.259*"game" + 0.061*"fun" + 0.040*"command" + 0.030*"play" + 0.024*"hacker" + 0.020*"hack" + 0.018*"puzzle" + 0.012*"soundtrack" + 0.012*"tool" + 0.011*"learn"
4	Challenge	0.044*"real" + 0.027*"point" + 0.022*"problem" + 0.020*"review" + 0.018*"challenge" + 0.015*"ui" + 0.015*"thought" + 0.014*"interested" + 0.014*"based" + 0.013*"unique"
5	Channel & Experience	0.052*"experience" + 0.032*"linux" + 0.021*"device" + 0.019*"read" + 0.016*"immersive" + 0.013*"fantastic" + 0.013*"understand" + 0.012*"machine" + 0.012*"change" + 0.012*"stuck"
6	Control & Added Value	0.065*"story" + 0.050*"time" + 0.031*"gameplay" + 0.026*"mission" + 0.024*"dlc" + 0.023*"hour" + 0.022*"playing" + 0.021*"interesting" + 0.021*"amazing" + 0.018*"worth"

about whether the content was worth the purchase price, which was also consistent with the results reflected in the previous periodic chart of the number of comments.

Among the other three topics with some overlap, Topic 3 reflected the content and enjoyment of the game; Topic 4 dealt with some additional attributes and content of the game, such as user interface, attributes, etc.; Topic 5 reflected the way users thought about the device and experienced the game; and Topic 6 reflected the topic of gameplay, storytelling, quests, and DLC (downloadable content, add-ons). After randomly sampling the samples under some themes, results showed that the content discussed in these themes had overlapping parts. For example, user reviews discussing the fun might also address the gameplay and storytelling, while reviews discussing the DLC might also discuss its fun and value.

Results showed the diversity of the motivations of different educational game users, consistent with previous research findings (Westwood & Griffiths, 2010). Like other game motivations, the pursuit of fun was one of the main intrinsic motivations of educational game users (Reid, 2012). On top of this, educational game users also focused on the meaning and goals of the game and the value it would bring. In addition, previous findings showed the design of achievements to be effective in increasing player motivation (Blair, 2011), which would also apply to educational video games.

4.4 6 C's learning motivational model (RQ2)

Table 8 shows 6 C's learning motivation model's six factors and associated topics and terms. Since the games selected for this study were all single-player games, the motivational factor of collaboration was not considered. The other five motivational factors were all reflected in the topics and terms discovered. Among them, *fun, play, hacker, hack*, and *puzzle* in Topic 3, *interested* in Topic 4, *immersive* and *fantastic* in Topic 5, and *story*, *gameplay*, *playing*, *interesting*, and *amazing* in Topic 6 reflected the motivational factors of choice, meaning users would choose the content they were more interested in.

The terms *problem*, *challenge*, and *based* in Topic 4 and *stuck* in Topic 5 reflected the motivation factor of challenge, meaning users could feel the difficulty and challenges of the game, and appropriate challenges might have some motivational effects on users. The term *money*, *open*, *average*, and *fast* in Topic 2, *ui* and *review* in Topic 4, and *mission* and *review* in Topic 6 reflected the degree of control users possessed over the content and progress of the game, indicating that users were concerned about their degree of freedom in choosing missions, as well as their degree of control over how to play and what to do with the game.

Control, a motivational factor, showed a natural advantage in self-regulation learning, where users enjoyed a high degree of autonomy and decision-making power over the content and progress of their learning, aligning with previous research on motivation in games based on self-determination theory (Leitão et al., 2022). The terms *file*, *server*, *terminal*, *text*, *simulator*, and *job* in Topic 1 and *tool*, and *job* in Topic 4 reflected users' understanding of the meaning and value of the game, indicating the game should contain a clear meaning construction for the user to understand the meaning and goals of learning clearly. The term "achievement" in Topic 1 was related to the motivational factor of consequences.

To reduce the bias of topic mining, the raw data was randomly checked to confirm whether the words "achievement" here contained negative factors. Examples included: "reviewing this with all achievements earned, I loved this game that much," "I guess now I will be on extensions and achievements hunting," and "I used some guides to get a few of the hidden achievements." These samples included some positive consequences of user "achievements," indicating the rewards of completing the

Table 8 Motivational factors and related words

Motivational factors	Related topics	Related terms
Choice	3, 4, 5, 6	fun, play, hacker, hack, puzzle, interested, immersive, fantastic, story, gameplay, playing, interesting, amazing
Challenge	4, 5	Problem, challenge, based, stuck
Control	2, 4, 6	money, open, average, fast, ui, review, mission, hours, time, dlc
Collaboration	\	\
Constructing meaning	1, 4	file, server, terminal, text, simulator, job, tool, learn
Consequences	1	achievement

game but not the negative ones, e.g., the consequences of the user giving up. This demonstrated a feature of unsupervised learning, where the user would easily give up because of no need to pay any price. The design of achievements, in this case, would increase user motivation, similar to previous findings (Westwood & Griffiths, 2010).

4.5 Categorized results and 6 C's learning motivation model (RQ3)

4.5.1 Recommend review with positive sentiments (Group 1)

Table 9 shows the top 20 important terms of Group 1 (the recommended review set with a positive or neutral sentiment) along with their TF-IDF scores.

Further analysis involved initially removing keywords common to both Group 1 (recommended) and Group 2 (not recommended) to focus on elements unique to each sentiment classification. Upon comparing the top 20 terms from Group 2 (see Table 12), distinctive keywords in Group 1 were identified, such as *Fun, Learn, Amazing, Cool, Hacker, Interesting, Challenging, Cat, Solitaire, Awesome, and Logic.* Furthermore, words closely related to the positive sentiment, such as *Fun*, *Amazing*, *Interesting*, *Awesome*, and *Cool*, were excluded because this group already showed positive sentiments from the sentiment classification results. In addition, the keyword *Cat* was removed after being recognized as a segmentation artifact from words such as "Categories." As a result, the keywords *Learn, Hacker, Challenging, Solitaire, and Logic* remained for qualitative examination.

The *Learn, Hacker, Solitaire, and Logic* keywords. First, all the reviews with these keywords were extracted. Then, the reviews were segmented, focusing only on the sentences exactly with these keywords. Results revealed a unified expression of learning experiences gained through gameplay. All sentences were qualitatively examined, and results indicated these sentences consistently expressed the learning gained in the game-playing process, indicating the significance of meaning construction in making an engaging game. Example comments included: "That's why I recommend this game, especially to people who like to learn while having fun," and "Sure, it doesn't help with actual programming on its own, but it offers plenty of opportunities to learn about procedures of programming nonetheless." (See Table 10).

The *Challenging* keyword. All review comments with this term ($n=202$) were analyzed. The result highlighted that a well-balanced challenge, not too difficult, was

Table 9 Top 20 terms for Group 1

Index	Word	Score	Index	Word	Score
1	game	628.73	11	cool	70.29
2	fun	339.46	12	hacker	67.76
3	puzzle	193.25	13	interesting	66.28
4	programming	131.08	14	challenging	66.10
5	play	94.39	15	cat	63.77
6	story	85.54	16	solitaire	62.79
7	time	83.41	17	awesome	58.53
8	learn	81.73	18	real	57.25
9	amazing	81.70	19	logic	56.58
10	machine	73.33	20	work	55.65

Table 10 Review comment samples from the "recommended with positive sentiment" group

Sample Review Comments
Constructing meaning (Keywords: *Learn, Hacker, Solitaire*, and *logic*) • [That's why I recommend this game especially to people who like to learn while having fun.] • [This game makes solving abstract math problems and learning how to think like a programmer fun!] • [Sure, it doesnt help with actual programming on it's own, but it offers plenty of opportunities to learn about procedures of programming nonetheless.] • [However, if you want to feel like a computer security hacker and would like to enjoy a cool story, you should try this.] • [The solitaire game was fun though.] • [If you love a good brain-bending logic puzzle, then this is the game for you.]
Challenge (Keyword: *Challenge*) • [Fortunately, one doesn't have to be a genius to enjoy this game; being fond of an interesting, well-designed series of challenges, and of learning by doing, seems enough.] • [However, for people not being too familiar with computer engineering, this definitely will be a good and educational challenge of how to use text based operating systems.] • [It is really hard to find a puzzle game that can truly challenge and teach me at the same time.]

Table 11 Top 20 terms for Group 2

Index	Word	Score	Index	Word	Score
1	game	16.30	11	play	2.49
2	boring	6.97	12	understand	2.45
3	puzzle	5.012	13	work	2.42
4	programming	4.72	14	command	2.40
5	machine	4.22	15	real	2.38
6	repetitive	3.62	16	pdf	2.33
7	tutorial	3.01	17	expected	2.15
8	time	2.87	18	buy	2.15
9	poor	2.80	19	documentation	2.06
10	guess	1.97	20	story	2.05

crucial in motivating players to engage with the educational video game, implying the difficulty of the task design was a key factor in player motivation. Examples include: "*Fortunately, one doesn't have to be a genius to enjoy this game; being fond of an interesting, well-designed series of challenges, and of learning by doing, seems enough.*" (See Table 10).

4.5.2 Not-recommend review with negative sentiment (Group 2)

Table 11 shows the top 20 terms of Group 2 (the review set that is not recommended and has a demotivating or neutral sentiment) and their TF-IDF scores. Among them, terms such as *boring*, *repetitive*, and *poor* reflected the poor enjoyment or lack of content in the games. Like Group 1, the motivation factor of choice influenced users in Group 2 more, focusing on whether the game could meet their interests. The pres-

ence of *expected* in Group 2 implied that some aspects of the game might not meet user expectations. In addition, *time* implied users did not have enough time or the game's length did not satisfy the users, which might relate to the motivation factor of control. The terms in Group 2 reflected the parts of the game where the motivation factor was poorly set, and improving these parts would help increase the users' retention rate.

Similar to the analysis conducted for Group 1, further analysis involved removing keywords common to both Group 1 (recommended) and Group 2 (not recommended) to focus on elements unique to each sentiment classification. Upon comparing the top 20 terms from Group 1 (Table 10), results indicated distinctive keywords in Group 2, such as *boring, repetitive, tutorial, poor guess, understand, command, pdf, expected, buy, and documentation*. Furthermore, words closely related to the negative sentiment (such as *boring and poor*) were removed as this group was found to have negative sentiments from the sentiment analysis classification results. Furthermore, the keyword *buy* was excluded because of its relation with the negative sentiment of the review comments, such as "don't buy it." As a result, the terms *repetitive, tutorial, guess, understand, command, pdf, expected, buy*, and *documentation* remained for qualitative analysis.

Results indicated poor documentation and lack of intuitive controls as significant de-motivators for the analyzed video game players. Specifically, the keywords *tutorial, guess, understand*, and *documentation* were central to these findings. The player comments expressed frustration over inadequate guidance, as evidenced by comments like *"There is no tutorial, but a 50-page manual is included"* and *"Game provides documentation, which is incomplete, many early problems are made trivial with operations not included in the documentation."* These analysis results indicated a clear need for improved, user-friendly documentation and tutorial mechanisms to enhance player understanding and engagement. (See Table 12)

Additionally, the terms *repetitive* and *command* highlighted another area of player dissatisfaction. Some players perceived the game as lacking in challenge due to repetitive tasks, undermining the game's engagement factor. Comments like *"It is just a very simple puzzle game, which gets repetitive after a few hours"* captured this sentiment. These results further confirmed the importance of challenges for educational video games (See Table 12).

4.5.3 Other reviews (Group 3)

Table 13 shows the top 20 terms and their TF-IDF scores for Group 3 (the review set of recommended with negative sentiments or not recommended with positive sentiments). The terms from Group 3 showed that different groups of users provided different feedback on different game dimensions. They reflected valid but insufficient motivational factors covering various topics. The terms *fun*, *interesting*, etc., indicated that users continued to focus on the fun aspects of games and whether they matched their interests, i.e., the motivational factors of choices. The terms *hard* and *level* reflected the difficulty and challenges of the game, while the terms *learn*, *machine*, and *work* reflected, to some extent, the users' concern with the construction

Table 12 Review comment samples from the "recommended with positive sentiment" group

Sample Review Comments
Poor documentation and without control (Keywords: *tutorial, guess, understand, pdf and documentation*) • [There is no tutorial, but a 50-page manual is included.] • [The tutorial pdf is designed to be opaque.] • [this game was almost impossible to understand.] • [Game provides documentation which is incomplete, many early problems are made trivial with operations not included in documentation.]
Not challenge (Keyword: *repetitive, command*) • [It is just a very simple puzzle game, which gets repetitive after a few hours.] • [The game teaches you some basics of data science and it is fun for a bit… but it gets repetitive quickly, besides limiting the tools you can use on each stage arbitrarily (i.e.: even if you have learned/used a concept before, you won't be able to use it later, which makes no sense)] • [Additionally, the actual gameplay is very repetitive, basically the same six commands with brief periods of waiting (there is a counter but it's easily stopped).]

Table 13 Top 20 terms for Group 3

Index	Word	Score	Index	Word	Score
1	game	56.07	11	playing	9.97
2	puzzle	23.36	12	hard	9.85
3	fun	17.49	13	learn	9.78
4	programming	17.31	14	level	8.82
5	time	13.37	15	real	7.78
6	work	12.89	16	solution	7.70
7	machine	12.87	17	dumb	7.67
8	play	10.75	18	command	7.62
9	brain	10.60	19	hurt	7.51
10	interesting	10.19	20	stupid	7.41

of educational meaning in the game. Enhancing these motivational factors would help further motivate users to play the game.

5 Discussions and recommendations

5.1 Recommendations for educational video game developers

Based on the above findings, we propose the following recommendations for game developers to promote the design and development of educational video games.

Firstly, the findings from the recommended positive sentiment group support the applicability of the 6 C's learning motivational framework to the context of educational video gaming motivation because the topics generated by the review comments fit in the five factors in the 6 C's learning motivational framework. In addition, our findings align with a motivational factors taxonomy created from a systematic literature review on the motivations of educational games by Laine and Lindberg (2020).

Secondly, the findings from the not recommended with negative sentiment group reveal that the "repetitive gaming elements" and the "poor documentation and tutorial" are the most significant de-engagement factors for the selected educational video games. Thus, educational game designers should: (1) provide clear and straightforward tutorial instructions, (2) make the game more intuitive to understand, and (3) reduce the repetitive elements of the game. Game developers should enhance the richness and fun of game content as much as possible to engage users and continuously reduce the abandonment rate. In the existing body of literature, the motivational factors of the game have been frequently explored and synthesized as different classes and taxonomies (Laine & Lindberg, 2020). However, de-motivation factors are seldom explored. This research provides a nuanced starting point for future research investigating "motivational factors" against "demotivational factors."

Thirdly, game designers should add clear descriptions and documentation on the educational meaning and goals of the game. Results indicate that meaning construction is one of the major motivations for users of educational video games. Therefore, game developers should clearly define the learning outcomes that users can achieve by experiencing different content and the value gained through a step-by-step process. Educational game design should be more closely linked to current research on how students learn (Coleman & Money, 2020). The tasks and processes of games should be organized around defined meanings and goals rather than meaningless piles of knowledge and content.

Fourthly, the educational game producers may pay attention to learners' reviews and feedback and explore the core needs to determine the direction of improvement to meet their needs. Using text mining techniques, the information users include in educational games' comments can be effectively analyzed to improve teaching and learning (Pacella & Marocco, 2022). The development of social media and online platforms has provided learners with channels to express their opinions and feelings and provided game developers with more textual information for feedback. Game producers should encourage learners to share their experiences in the community with incentive schemes, thus forming communities of learning and practice (Jiang et al., 2023; Lei et al., 2021; Xie et al., 2023a). This research demonstrates that mining online comments can further understand the game experience from user perspectives and improve it in a targeted way. The game developers may apply our flow of analysis to their data.

Lastly, game developers should comply with ethical rules and use motivational factors correctly to avoid the negative effects of inappropriate incentives on users and society. Prior studies have shown that some questionable video games enhance player motivation by exploiting realistic needs and frustration (Mills et al., 2017), which may increase the risk of players engaging in addictive behaviors (Reid, 2012), negatively impacting society's perceptions of games. Therefore, educational game developers should think dialectically about the benefits and harms of game motivational factors and use them selectively to promote positive social feedback on educational video games.

5.2 Recommendations for users

These findings also lead to some recommendations for users of educational video games. Previous studies have shown that educational video games help change learners' behavior by enhancing their motivation. Thus, users should actively attempt new modes of learning exemplified by educational video games to experience a more immersive and interactive learning experience (Gee, 2013) that enhances intrinsic motivation and facilitates learning. Furthermore, to reduce the adverse effects of video games, users should experience educational video games with a reflective and critical mindset, actively seeking out the value of the game content and its meaningful connections to real-world behaviors (Squire, 2008). Additionally, users may apply transferable knowledge gained from games to real-world scenarios to promote their own behavior change and skill development (Gee, 2013). Finally, we encourage users to participate in discussions or communities to supplement the lack of motivation for cooperative behavior in single-player games. Sharing and reflecting on the gaming experience promotes a deeper understanding of the behavioral changes facilitated by the game (Shaffer et al., 2005), which further contributes to learning and personal development (Lei et al., 2021).

Additionally, users should pay proper attention to game reviews and utilize information on social media to filter games quickly and efficiently. The development of the Internet has led to a vast amount of available information on social media and platforms, including game reviews, user evaluations, etc., through which users can efficiently screen their target games to find an educational video game that meets their goals quickly. However, the information on the Internet is complicated and contains some false or malicious information, requiring users' higher recognition ability to avoid being misled by such information (Ho et al., 2022).

To have a clear and comprehensive understanding of video games' positive and negative impacts and to avoid following the trend of praising or belittling them. The public perception of the video game industry is mixed (Funk & Buchman, 1995), with some questioning whether video games are suitable for educational purposes. As users, it is more important to understand the positive effects of video games, their addictive properties, and their underlying causes (Wood, 2007) and to think about their role dialectically. At the same time, improving self-management skills, developing reasonable gaming arrangements, and avoiding exposure to problematic games enhance player motivation by exploiting realistic needs and frustration (Mills et al., 2017). The development of the industry requires the joint efforts of game producers, users, and other stakeholders.

5.3 Recommendations for educators and educational institutions

Findings have uncovered the main motivations of users to learn with educational video games, leading to the following suggestions for educators.

Educators may leverage the potential motivational factors of video games to promote learning and behavior change. Educators can use educational video games as an assistant teaching tool to improve learners' motivation. Taking programming games as an example, they stimulate users' interest in programming and provide them with

a higher sense of achievement through integrating motivational factors compared to learning programming languages directly (Xie et al., 2023). According to Tikva and Tambouris (2022), coding games are especially helpful in promoting the participation of students with less positive attitudes towards programming. Even though block-based visual programming platforms such as Scratch offer greater expressiveness (Wong, 2023), by limiting the options within a set scenario, coding games may make students feel more empowered to program within the game. Therefore, educators can increase learners' motivation and promote their computational thinking skills by, for example, introducing students to educational video games or arranging them as assignments.

Educators should carefully select games that meet specific learning objectives, provide genuine problem-solving skills that promote personal development (Squire, 2008), and avoid exposing students to inappropriate games. By incorporating educational video games, educators can create positive and motivating learning environments that facilitate learners' active participation in learning and the development of critical thinking and skills related to the real world (Prensky, 2001; Shaffer, 2006). Additionally, educators should encourage reflection and discussion among students so that students can clearly understand the behavioral changes they experience (Dong et al., 2021; Lei et al., 2021) while experiencing an educational video game and apply the knowledge and skills they learn, as well as the positive changes in their behavior, to real-life situations (Shaffer et al., 2005).

Furthermore, as a group more knowledgeable about learning content, educators can collaborate with game developers in developing educational video games to make them more applicable to real-world teaching and learning environments and, simultaneously, to further develop meaning construction. Even with the strong potential demonstrated by games to improve teaching and learning, Dahalan et al. (2023) point out that incorporating games into curricula requires a great deal of creative ability and production time. Therefore, the involvement of educators who are more familiar with existing curricula can help save production time and increase the effectiveness of outcomes.

6 Conclusion, limitations, and future work

This research investigated the motivational factors in user reviews of programming educational games through sentiment analysis and LDA topic modeling using 6,228 Steam Community reviews collected. Sentiment analysis revealed that changes mainly influenced the number of game users' reviews in the game's price and leisure time, and the ratio between different sentiment categories was largely stable. LDA topic modeling identified six topics, "technology & content," "reality," "fun & meaning," "challenge," "channel & experience," and "control & added value." Guided by the 6 C's learning motivation model, results indicated that the motivation of educational game users is related to choice, construction meaning, challenge, and control. Among them, users focus on whether the game content meets their interests and whether the educational significance of the game is well constructed. Users in different review groups have high expectations of the game's interestingness, which can

be used to motivate players further. Control is a motivational factor that users usually ignore, probably because video games inherently have the advantage of a high degree of user control. However, this advantage may also be an important factor leading to user abandonment when the game is not sufficiently interesting and attractive. Further analysis also revealed de-motivation factors that are rarely explored. Therefore, we propose effectively engaging players and increasing retention by enriching content choices and good meaning construction.

The field of educational video games discussed in this research is still emerging and does not yet have much previous research, making it difficult to compare the results with existing findings. In addition, only programming games were selected for this research, and the conclusions need more research for generalizability. The data for the research came from a single-game forum, which may have a sample bias. Yet, the nature of the sentiment analysis and text mining research methods enabled this research to focus on the phenomena and explore the theoretical basis guided by the 6 C's learning motivation framework. In addition, due to the richness of language, keywords may also represent other meanings, leading to biased conclusions.

Based on the above limitation, future research in this field can consider expanding the scope of sample collection, which can be used to validate the existing findings and improve generalizability. For example, other types of educational games can be chosen as research subjects, or data can be obtained from different forums. The motivational factor of collaboration should also be investigated. In addition, researchers should investigate the reasons behind these motivations more in-depth to provide a deeper theoretical basis for the phenomenon. Finally, other more precise research methods can be explored to minimize the bias of conclusions caused by research methods.

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Data availability Data are available upon email request to the corresponding author.

Declarations

Ethical approval The faculty-level ethics committee approved this research. Human Research Ethics Committee, Faculty of Education, The University of Hong Kong approved this research.

Consent to participate This research only involves the analysis of data from publicly accessible websites.

Conflict of interest Authors declare no conflict of interest.

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Authors and Affiliations

Yitong Chen[1] · Zerong Xie[1] · Dickson K.W. Chiu[1]

✉ Yitong Chen

yitchen@connect.hku.hk

✉ Zerong Xie
zerong@connect.hku.hk

✉ Dickson K.W. Chiu
dicksonchiu@ieee.org

[1] Faculty of Education, The University of Hong Kong, Pokfulam, Hong Kong