

# The Impact of Mobile Educational Games on Contemporary Users' Learning Behavior

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## ABSTRACT

The purpose is to cope with mobile educational game users' low continuous utilization rate. This thesis innovatively introduces the deep learning technology to study and the relationship between the mobile educational game and learners' learning behavior. It is found that learners' game experience is significantly correlated with game satisfaction. The estimation algorithm is designed based on the convolutional neural network (CNN), and the questionnaire method is adopted. The design tool of the estimation algorithm is a computer system, and the social software is used for the questionnaire. The dataset source used in the estimation algorithm design is "World Sudoku Championship." The game satisfaction questionnaire and learning behavior questionnaire subjects are 60 primary school students and 300 college students, respectively.

## KEYWORDS

Convolutional Neural Network, Deep Learning, Learning Behavior, Mobile Educational Games, Satisfaction

## INTRODUCTION

### Research Background and Motivations

With the popularity of electronic games, mobile educational games have been widely developed (Rahimi et al., 2021). However, learners seem to be prone to slack psychology, which is related to their learning behavior in educational games (Hines et al., 2021). Mobile educational games combine learning with games to make learners learn knowledge while playing games (Shute et al., 2021). Learning in the 21st century should be relaxed and pleasant, which can be combined with entertainment to enable learners to carry out learning activities in a relaxing atmosphere (Robert, 2020). Although educational games have broken the traditional learning mode, their development speed is far behind that of other electronic games (Schmidt et al., 2020; Zheng, Liu, Ni, et al., 2021).

The main audience of educational games initially developed is children (Nizam & Law, 2021). The original educational game aims to improve children's interest in learning by enriching interesting images and finally improving their map reading ability (Marston et al., 2020). With the progress of mobile devices and social media, the content of educational games is richer, with more audiences from various fields (Havukainen et al., 2020; Harley et al., 2016). For example, with the progress of social media, users have adopted educational games on social platforms, and developers of educational games also start to use some promotional means of "discount after a certain period of clock in"

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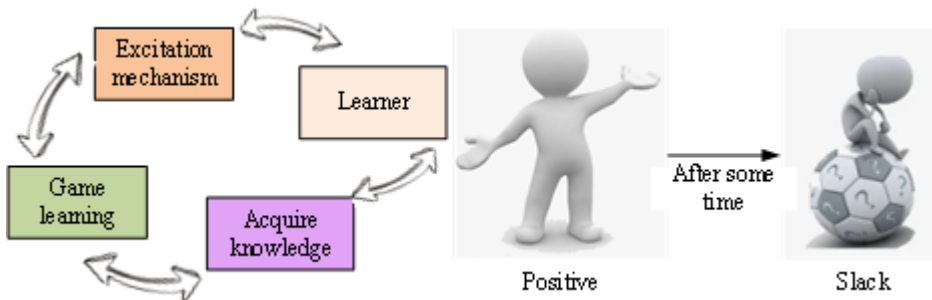
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(Jung, 2020). The rapid development of online education in China has led to the emergence of mobile learning payment modes, and more and more users are willing to pay for educational games (Yu et al., 2021; Xiong et al., 2022). However, the user persistence rate of educational games is low. The current research focuses on improving the user experience and triggering user repurchase behavior (Dubé & Dubé, 2021).

Figure 1 shows the basic situation of current mobile educational games. Learners often have slack psychology after learning for some time. Solving this problem is one of the difficulties faced by educational games.

Figure 1. Current situation of educational games



Some achievements have been made in the research on educational games (Ruipérez-Valiente et al., 2021). For example, educational game enterprises have realized the importance of educational entertainment in the digital environment, and many companies have also joined the ranks of studying educational games (Huda & Ramadhan, 2021). However, their application is limited to certain specific subjects and occupations, such as educational games simulating cancer treatment and teaching pharmacology (Shi et al., 2020; Zenggang, Mingyang, et al., 2022; Zenggang, Xiang, et al., 2022). The research and development of existing educational games are mostly carried out in the game enterprise, which is highly commercial (Wang & Han, 2021). Their best-selling degree is lower than the existing educational games due to the improper coordination between educational and game factors. In addition, the development of educational games needs more costs. Considering the profit, many game companies have made no more attempts in this field. Educational games developed by educational institutions often rarely grasp the scale of game factors, and the finished products are more inclined to educational software, so it is difficult to stimulate student learning interests. In educational games research, there are many problems to be solved.

## Research Objectives

In order to develop educational games that can stimulate student learning interest and the improvement direction of educational games, first, the research status of educational games and learning behavior was reviewed. Based on those findings, a mobile educational game based on a convolutional neural network (CNN) was designed. Finally, student learning behavior in mobile educational games is analyzed using deep learning (DL), combined with social media to analyze learning behaviors from the interactive dimension. The research provides a reference for the effective practice of educational games. The findings provide a direction for the wide application of artificial intelligence (AI) technology in educational games.

## LITERATURE REVIEW

Foreign research about educational games was started in the 1980s. The earliest study integrated video games into instructional design. Researchers integrated learning theory, flow theory, and game design theory into educational game design and developed an educational game model with a sense of experience. The model focused on timely feedback and clear objectives adapting to players' skills (Liu et al., 2020; Zheng, Liu, & Yin, 2021; Zheng, Yin, et al., 2021). The development of foreign educational games mainly involved the mutual cooperation between game development enterprises and schools to ensure the simultaneous development of education and entertainment of games (Triantoro et al., 2020). For the conceptual model of interactive educational media, Microsoft and the Massachusetts Institute of Technology have developed the conceptual framework of game interface teaching software suitable for natural science, mathematics, and engineering (De Jonge & Zhang, 2020; Leditzky et al., 2020). The development of educational games in China started very late. Based on the idea of providing a game-based and effective learning environment for players, some scholars have constructed an educational game design model to encourage learners to participate in learning activities actively (Rahimi et al., 2021; Blumberg et al., 2020).

The research on online learning behavior abroad mainly focuses on three aspects. First, the e-learning environment is studied based on the needs of school students. Learning performance and learning behavior are compared. Researchers established online learning environments and strategies based on learner needs by comparing the learning behavior records, learning needs, and personality characteristics of e-learners in different network environments (Zhai et al., 2018). Some studies have also investigated students' game activities combined with current mobile devices. For example, Huizenga et al. (2019) surveyed the virtual game participation of middle school students. They found that the degree of empathy of students for game characters seemed to be negatively correlated with their interest and knowledge of the subject. Acquah and Katz (2020) concluded that digital learning games might be beneficial to language acquisition, psychological state, and participation behavior by studying student digital game behavior in East Asia and the Middle East (Acquah & Katz, 2020).

Tool software is used to record, analyze, and track online learning behavior. Some scholars access log files through the database of online learning platforms to explore learning behaviors (Adeyemi et al., 2021; Barros et al., 2020). Moreover, theoretical analysis is adopted to measure online learning behavior. The researchers put forward five dimensions of online learning measurement: participation, social, interaction, cognitive, and metacognitive dimensions (Jackson & Jackson, 2021). Domestic research on learning behavior mainly uses data analysis and theory. Researchers obtained four variables of online learning behavior by investigating and mining data, namely *online homework level*, *on-demand level*, *platform level*, and *posting level* (Vermeiren et al., 2022).

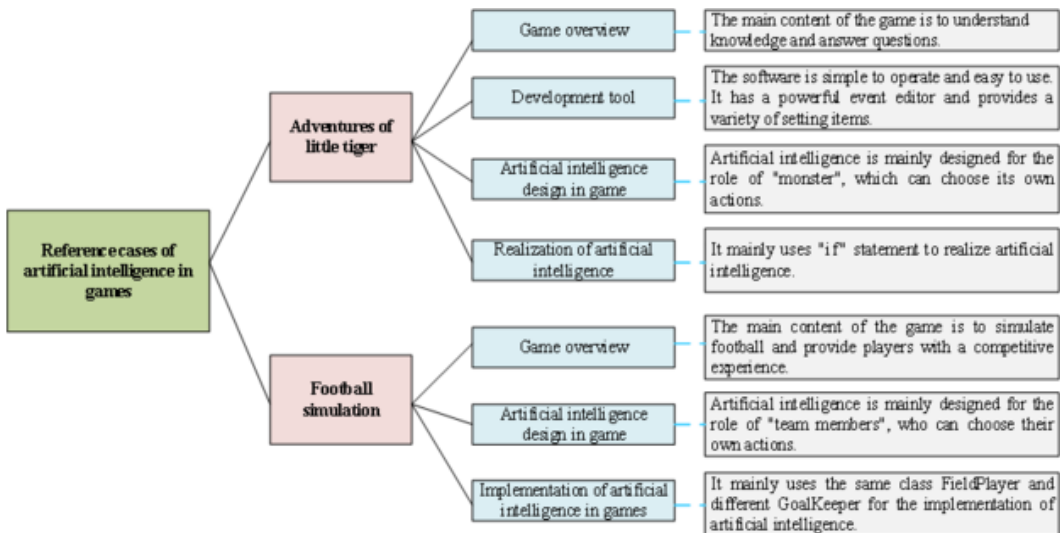
Although some results have been achieved in the research on educational games, educational game design, theories, and application models still need to be deeply studied. The research status of learning behavior is one of the crucial theoretical bases of this thesis. It reveals that educational games can promote learning behavior, and the interaction among students will promote the generation of learning behavior. However, there is little research on the interaction among learners in the current research. Therefore, the study is divided into two parts: (1) the design of a mobile educational game based on DL and (2) the analysis of learning behavior in the educational game combined with social media design. The research results are to get a more optimized mobile educational game and obtain the impact of mobile educational games on learning behavior. This study aims to explore the relationship between learning behavior and educational game satisfaction and promote learning behavior in educational games.

## RESEARCH METHODOLOGY

### Design Method of Mobile Educational Games

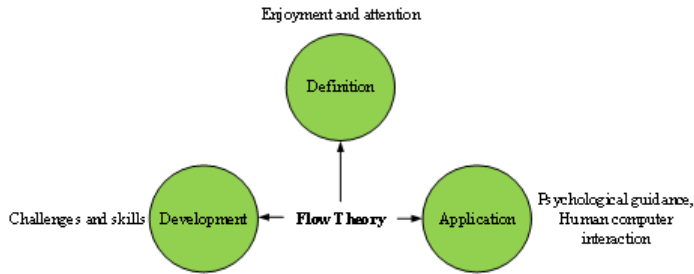
The basis of mobile educational game design comes from previous research. First, the current implementation methods of educational games combined with AI technology are summarized to find out the correlations and provide a reference for the game design. Figure 2 reveals that AI technology has different applications in games with different logical difficulties. For example, a more complex AI agent needs to be set in a sport simulation game. Hence, the practical application of the agent is simplified. The AI technology is used in educational games. On this basis, the agents to be added to the game are considered, and then appropriate methods are adopted to realize the combination of agents and educational games (Talib et al., 2021). The design of AI in educational games is mainly realized by an if-statement. AI technology is added to the agent design to provide users with a better educational game experience.

Figure 2. Implementation of intelligent educational games



The research objects are logic-oriented educational games in which an agent is required to play games with other players. Therefore, this study focuses on applying a CNN estimation algorithm in agent games after the game design. Educational games combined with the development of logical thinking are designed. The basic theories used include game design theory, flow theory, and game learning theory. Figure 3 shows the main content of flow theory. The rational application of flow can improve flow experience in educational games, enhance their persistence, effectively mobilize their enthusiasm, and finally improve the efficiency of acquiring ability and knowledge. AI in educational games is mainly realized through conditional statements (e.g., if-then statements). The educational games will be constructed based on flow theory.

Figure 3. Definition and application scenario of flow theory



The design of educational games is combined with the concept of game learning. Figure 4 shows the main content of the game-based learning concept. Game-based learning can penetrate the learning process into the game, significantly improve student learning interest, liberate them from the traditional tiresome learning process, stimulate their enthusiasm and make the transmission of knowledge interesting and vivid.

Figure 4. Main contents of game learning concept

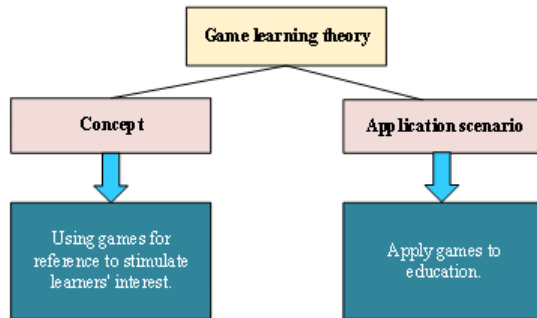


Figure 5 shows the overall elements of educational game design here. The constituent elements of educational games are consistent with other games, including role design, interface design, level design, rule design, and feedback design. These elements will be used reasonably in the later sections to design the mobile educational game.

Figure 5. The core content of the game design concept

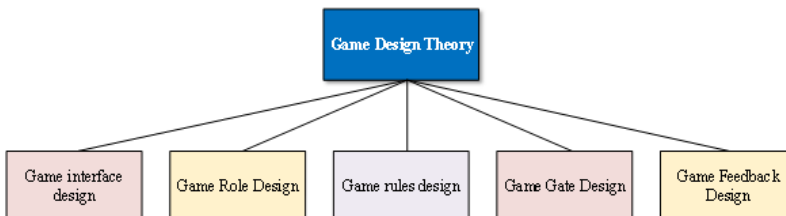
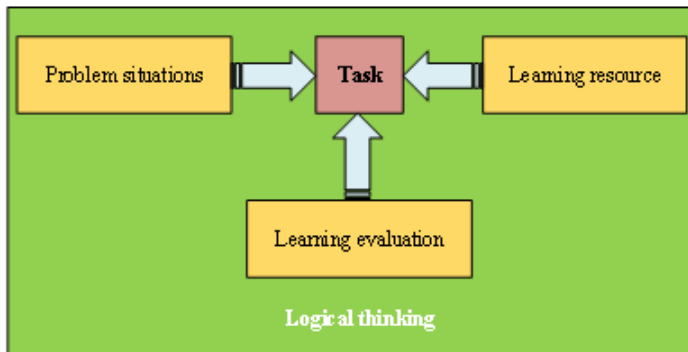


Figure 6 presents mobile educational game design elements and structure based on the above theories. The education part of mobile educational games is logical thinking ability. The constituent elements of the mobile educational game include tasks, learning resources, logical thinking ability, problem situations, and learning evaluation. This mobile game is to carry out learning activities through game characters and integrate learning tasks into game tasks. This method is consistent with the flow method mentioned above. It can effectively improve a learner's sense of flow and develop logical thinking.

Figure 6. Structural analysis and design elements of educational games



The *Space Goats* game (Griffiths & Pontes, 2020) served as the basis for an instructional design framework for educational games. The game teaches programming through graphics, combining a graphic program language with game characters. Players arrange graphical script language elements. The game aims to promote logical thinking. Figure 7 shows the advantages of the game. The game is based on the flow method and promotes logical thinking. The game is for primary school students, so the game setting is relatively simple, and the graphics and background music are relatively rich. The agent in the educational game was based on this game concept.

Figure 7. Advantages of case game

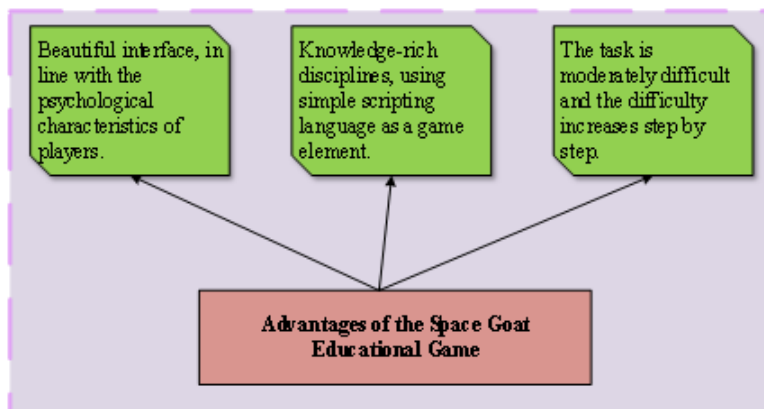


Figure 8 presents the instructional design framework of mobile educational games, including specific task design, learning goal analysis, game learning, learner analysis, feedback and modification, and game learning situation design. First, learning objectives and learners were analyzed. Next, the game learning situation was designed with relevant dimension analysis and logical thinking. The core part of the design framework was the design of game tasks. Finally, the appropriate development tools were selected for learners to learn games. Developers modified and optimized the game in response to learner feedback. The feedback module uses social media; learners can also communicate with other learners using the feedback module.

Figure 8. Instructional design framework

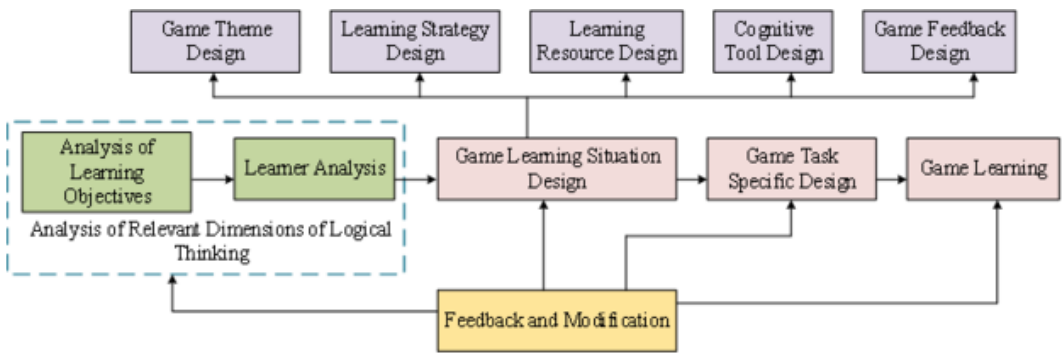


Figure 9 shows the learning mechanism of mobile educational games based on Sudoku. Learners first read the game description, select the game difficulty, and then enter the game. They think and judge according to the task during the game and learn with their classmates. According to whether the answer is correct or not, learners will be alerted whether the challenge is successful or failed and then choose to reset the game or exit the game. If learners continue the game, they will enter the next cycle; otherwise, the game is over.

Figure 9. Learning mechanism of mobile educational games

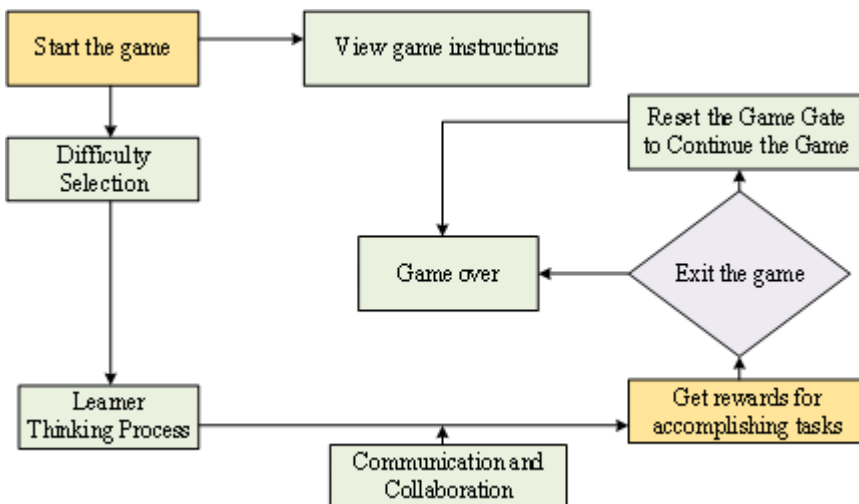
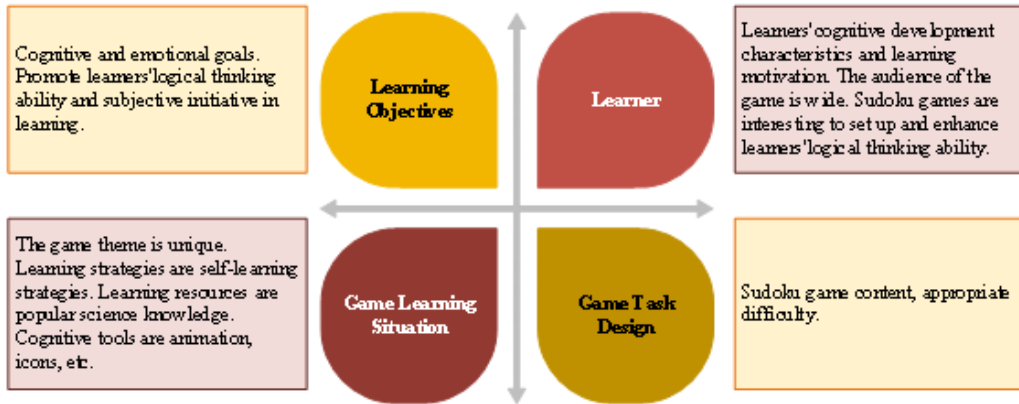


Figure 10 shows that the core link of the game is game scenario design. It takes Sudoku as the game basis and adds popular science knowledge. The game interface is rich, which is convenient for learners to accept the game. This provided reasonable and feasible suggestions for improving educational games.

Figure 10. Teaching design of educational games



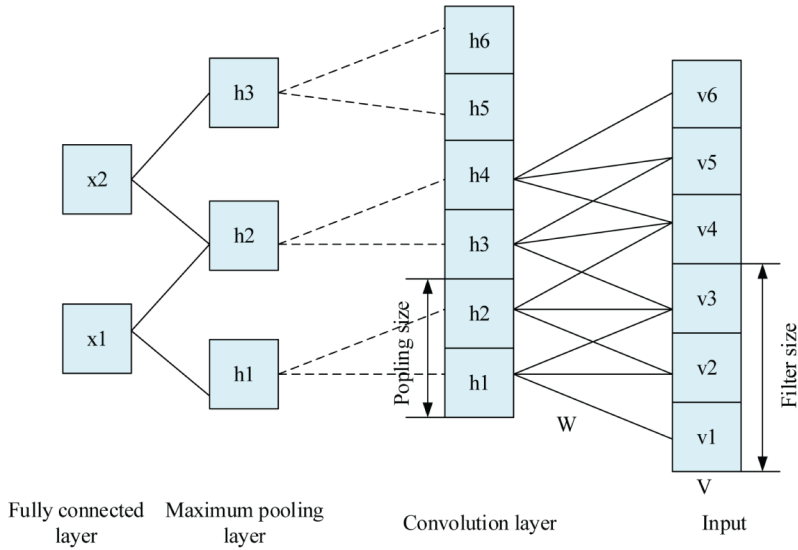
### Agent Design Method

Agents were added to Sudoku games to play games against players. First, the CNN is introduced, as shown in Figure 11;  $x$  represents the input value,  $h$  is the intermediate value,  $v$  is the final output value, and  $X$  represents the weight. The CNN includes a maximum pooling layer, a convolution layer, and a fully connected layer. Thus, it is a feedforward neural network. The convolution layer alternates with the maximum aggregation. Each neuron is connected to another neuron. In the fully connected deep neural network, the input of each hidden node is calculated by multiplying the whole input by the weight of the layer. The input of each hidden layer node is calculated by multiplying part of the local input by the weight and then sharing the weight in the whole space. Neurons in a given layer have the same weight. Weight allocation is the key principle of CNN. It helps to reduce the total number of training parameters and produce more effective models and training.

The pool function keeps features unchanged in position and summarizes the output of multiple neurons in the convolution layer. A typical pool function is *max pooling*, which divides the input data into a group of non-overlapping windows. It outputs the maximum value for each sub-region, which reduces the computational complexity of the upper layer and provides a form of transformation invariance. To be used for classification, the CNN's computing chain ends with a fully connected network, which integrates the information of all locations in all feature maps of the lower layer. The intelligent agent in educational games will play games with learners. CNNs can avoid the problems of too large a search space and inaccessible part of the information in an incomplete information game, making it an appropriate estimation model for this project.



Figure 11. CNN structure



The network input content of the model is the number filled in after learner input content was analyzed. There is little difference in the valuation of the game situation between the two adjacent layers in the actual game process.  $S$  is set as the game state, and  $E$  is the valuation function. In the actual game process, the game agent can determine the valuation of the game situation at the final moment, which is defined as:

$$E(S_n) = 1 \tag{1}$$

$$E(S_n) = 0 \tag{2}$$

Equation 1 indicates winning, and Equation 2 indicates losing. The valuation of Level  $i$  is based Level  $i-1$ , so the valuation can be obtained using Equation 3:

$$E(S_{n-1}) = \gamma \cdot E(S_n) \tag{3}$$

provides the valuation parameter for adjusting different game situations. After the equation is generalized, Equation 4 is obtained:

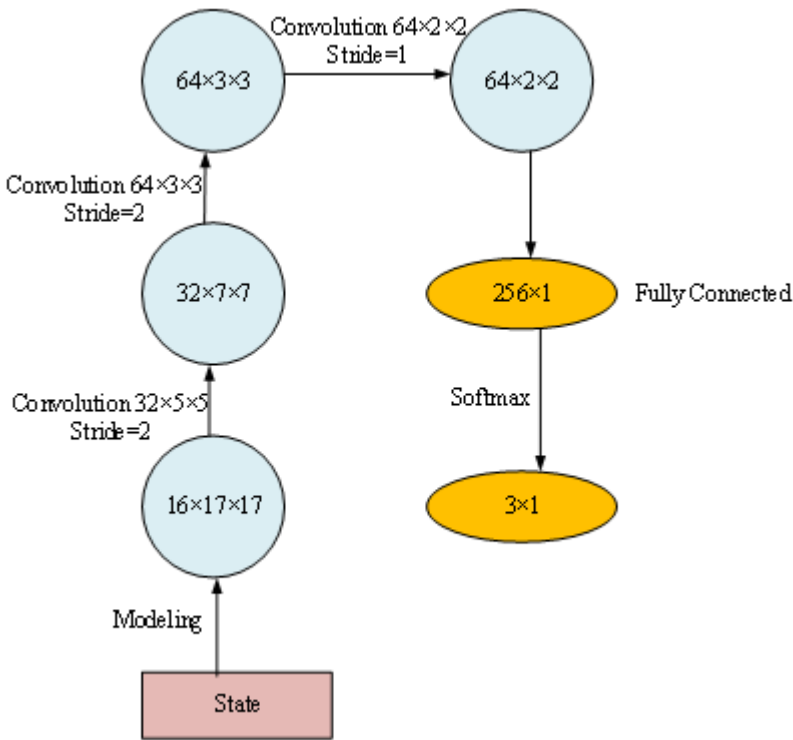
$$E(S_{t-1}) = \gamma \cdot E(S_t) \tag{4}$$

is the time of the game. The expected output at the final moment of the game can be obtained by combining Equations 1 and 2. The previous moment can be obtained according to Equation 3. The output layer should contain three nodes, which correspond to three choices of players in the game process: *give up*, *continue*, and *pause*.

Figure 12 shows the final network structure. There are three convolution layers of the estimated network, and the size of the fully connected layer is  $256 \times 1$ . Finally, the weighted output is input to the SoftMax activation function for normalization. The activation function of the convolution layer is the rectified linear unit (ReLU). The function expression reads:

$$y_i = \begin{cases} x_i, & x_i \geq 0 \\ 0, & x_i < 0 \end{cases} \quad (5)$$

Figure 12. CNN structure



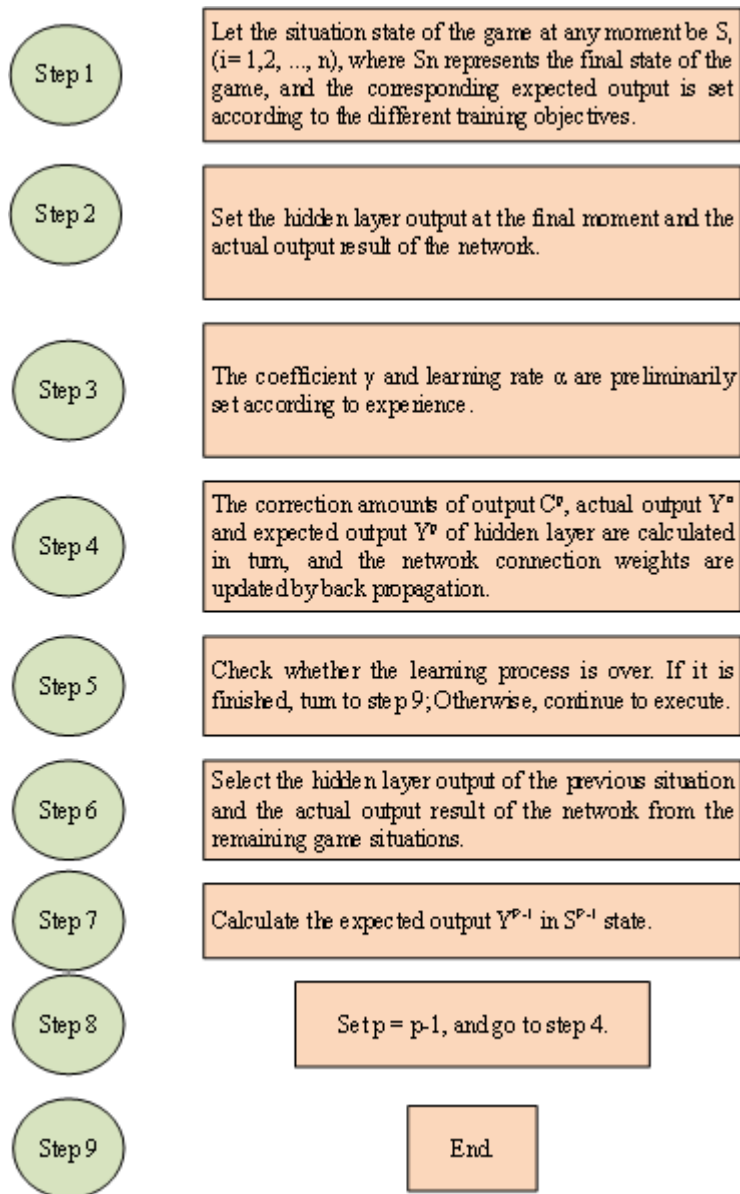
The sparse input matrix selects the AdaGrad gradient descent algorithm, and the evaluation function is set. Finally, the maximum value of  $Y$  is taken. The neural network model adopts the MSRA initialization method, accelerating network convergence.

The expression of the network error at the time reads:

$$\varepsilon(S_{n-1}) = \frac{1}{2} \sum_{k=1}^m (y_k^{p-1} - y_k^{n-1})^2 \quad (6)$$

To sum up, Figure 13 shows the flow of the CNN-based estimation algorithm. Figure 13 shows that the CNN estimation algorithm consists of 9 steps.

Figure 13. The flow of the CNN-based estimation algorithm



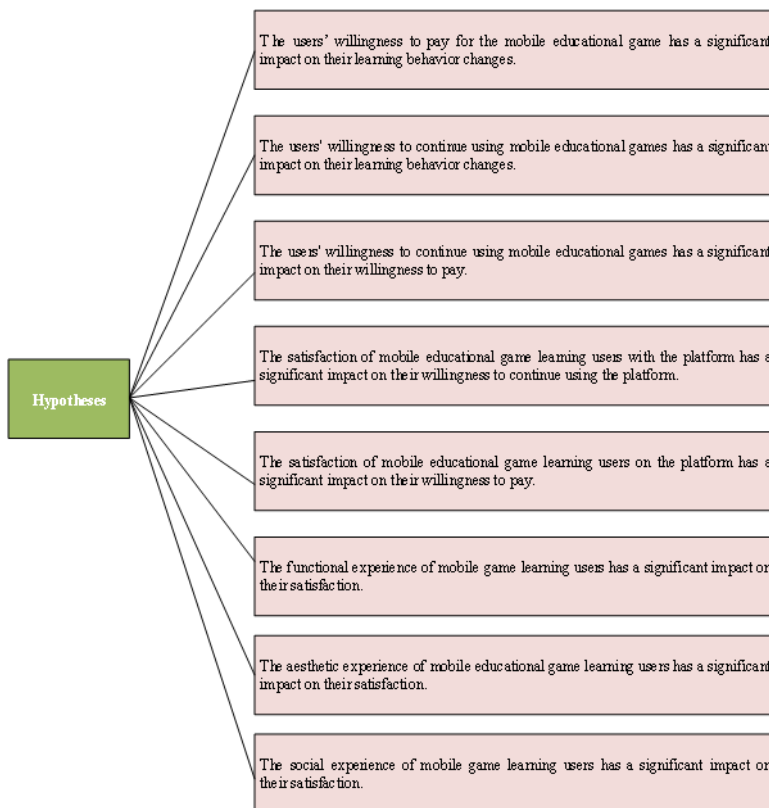
### Influential Model Construction Method

Figure 14 presents the assumptions of influencing factors based on the related concepts of game learning theory and learning behavior. The analysis is based on the assumptions in Figure 14. The study of learning behaviors involves user payment behavior, so the research was conducted with

college students. First, a preliminary survey was conducted, including two parts. The first part was the basic personal information, use of educational games, and monthly disposable income. The second part was the investigation of 28 index items with 7 latent variables. A 5-point Likert scale was selected for item measurement.

Overall, 120 questionnaires were distributed, and 107 were recovered, with a recovery rate of 89.2%. SPSS 25.0 was used for data analysis. Kaiser–Meyer–Olkin (KMO) and Cronbach’s  $\alpha$  coefficient method were used for the validity and reliability of the preliminary survey. In the reliability test, the Cronbach’s  $\alpha$  coefficient of each variable was higher than 0.8, indicating good reliability. All measured items had a KMO = 0.900, far greater than 0.7, which reached the significance level and suggested good validity. Hence, the measurement items of each variable reached the level of factor analysis, and the questionnaire could be officially issued. The formal questionnaire was conducted in combination with online social media.

Figure 14. Assumptions of influencing factors of learning behavior



Overall, 300 questionnaires were distributed, and 249 were completed, with a recovery rate of 83%. To test the internal consistency of the formal questionnaire data, first, the reliability analysis function of SPSS 25.0 was used to detect the Cronbach’s  $\alpha$  coefficient of the whole scale and each measurement variable. Generally, the scale’s reliability was excellent when the coefficient was higher than 0.8. The scale’s reliability was better when the coefficient was higher than 0.7. SPSS analysis showed that the overall Cronbach’s  $\alpha$  coefficient value of the scale was 0.960, and the Cronbach’s  $\alpha$  coefficients for each item were higher than 0.8, indicating that the overall reliability of the scale was

excellent, and each measurement variable had high reliability. In the formal questionnaire validity analysis, first, SPSS 25.0 was used to conduct exploratory factor analysis on the measurement items of the questionnaire to test the structural validity among the variables.

It was generally believed that factor analysis could be carried out on the questionnaire data only when the KMO value reached more than 0.7 and the significance level of the sphericity test met the significance requirements of the two-tailed test. The results showed that  $KMO = 0.924 > 0.7$  and  $Sig. = 0.000$  (very significant), indicating that the data collected by the questionnaire had a good concentration and was suitable for factor analysis. The factor load of each variable measurement item was higher than 0.7, suggesting that the variable dimension division was reasonable and had good structural validity.

After the reliability and validity analysis, a confirmatory factor analysis was conducted to analyze the questionnaire's convergent validity and discriminant validity. Composite reliability and mean extraction variance were common indicators of convergent validity. Based on the variance inflation factor, the model rationality was tested, and the path analysis was carried out. The path fitting was carried out in Smart PLS 3.0 software combined with the ordinary least squares.  $R^2$  and  $Q^2$  in the partial least-square method could reflect the prediction ability and stability of the structural model.  $R^2$  was the prediction performance index of the model, and  $R^2 > 0.5$  indicated a strong prediction ability in the model.  $Q^2$  was the prediction correlation index of the model. If  $Q^2 > 0$ , the model has a prediction correlation.

## EXPERIMENTAL DESIGN AND PERFORMANCE EVALUATION

### Dataset, Collection, and Environment

The data used in the agent performance test are from the competition data of the World Sudoku Championship, with 40,000 and 200,000 records in the dataset randomly selected to be the test set and training set, respectively. The training set was divided into four subsets, and each subset contained 50,000 data. The calculation of the result accuracy reads:

$$acc = \frac{1}{n} \frac{1}{4} \sum_{i=1}^N \sum_{k=1}^4 \left( I(y_i^k = \hat{y}_i^k) \right) \quad (7)$$

The performance is good when the convergence rate is greater than 85%. The winning and losing results of the designed agent were compared with those of the other two common agents, and the average reward obtained in each game was taken as the characterization result.

Considering that primary school students have high requirements for game satisfaction, a survey of educational game satisfaction is finally carried out among third-grade students at a primary school. Overall, 60 copies of the questionnaire were distributed, with an effective rate of 100%. Statistical Product and Service Solutions (SPSS) 25.0 software was used to analyze the questionnaire data. The questionnaire content included game multimedia, game information, game content, game interface, and game feedback. The questionnaire adopted a 5-point Likert scale, with 1 indicating *most dissatisfied* and 5 indicating *most satisfied*. The research on the impact of learning behavior involved user-paid projects and had certain requirements for the autonomy of learning behavior, so the research was conducted with college students. The questionnaires were divided into a preliminary questionnaire and a formal questionnaire. The formal questionnaire was conducted in combination with online social media. Overall, 300 copies of the questionnaire were distributed, and 249 were recovered, with a recovery rate of 83%. The research materials provided sufficient support for the research results. Table 1 presents the experimental environment.

Table 1. Experimental environment

Name	Attribute	Test Type
Model	E5-2620 v4 Dell T430 server	Agent testing
Central processing unit	2.1GHz Xeon E5-2620 v4	
Operating system	64bit Window Server 2012 R2	
Memory	16GB 2400MT/s RDIMMs	
Graphics card	8GB NVIDIA Quadro P4000	
Platform	Android	
Development tool	Cocos2d-x	
Computer language	C++	
Operating system	Windows operating system	
Image processing	PS	
Music processing	Cool Edit	

### Parameters

The convolution neural network in this study is set up into three layers: the hidden layer of the first song has  $325 \times 5$  convolution kernels with a step size of 2; The second hidden layer has  $643 \times 3$  convolution kernels with a step size of 2; The third hidden layer has  $642 \times 2$  convolution kernels with a step size of 1. Finally, a full connection layer with a size of  $256 \times 1$  is connected. The last layer of the network has three nodes.

### Performance Evaluation

First, the accuracy of the proposed estimation algorithm was analyzed. Figure 15 shows the results. The accuracy of the constructed CNN-based estimation algorithm increased with an increase in the experimental data amount. The final algorithm accuracy converged at 89%, which is a little higher than the 85% excellent standard line from the study by Park et al. (2021). It shows that the valuation algorithm constructed is feasible, and the AI agent based on this algorithm has good performance in mobile games. The accuracy of the estimation algorithm will directly affect the overall sense of the experience of educational games.

Figure 15. Accuracy of the estimation algorithm

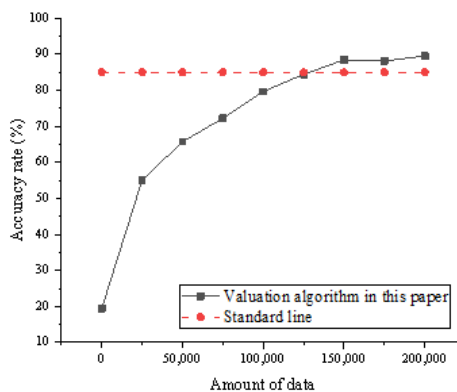
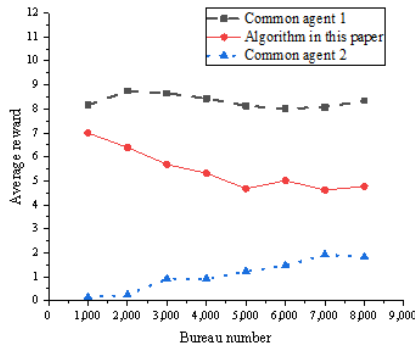


Figure 16 shows the performance comparison result between the AI agent constructed by the algorithm proposed and other common agents. The agent's performance based on the estimation algorithm is between Common Agents 1 and 2 studied by Rheu et al. (2021). The performance of Common Agent 1 is the best, which is mainly reflected in that it obtains more than 8 rewards during the game. The reward of the agent constructed is between 6 and 7, and the reward of Common Agent 2 is between 0 and 2. This suggests that the agent's performance is not optimal but is acceptable. The experimental agent will complete the operation of socializing with players in the whole mobile educational game system to increase player interest.

Figure 16. Comparison between experimental agent and other agents



The questionnaire participants included 32 boys and 28 girls, a relatively balanced gender ratio. Figure 17 is a satisfaction evaluation of the game. Figure 17 reveals that learners' overall evaluations of the designed logical educational games were high, and their satisfaction with the five dimensions of the game basically stayed above 3, which is better than the game satisfaction in Skowronski et al. (2021). The game's information and feedback scores are low, and the highest satisfaction is the game screen and multimedia. The average satisfaction is 4.75 and 4.68, respectively. The shortcomings will be used as the future optimization direction. Because of the construction of the CNN-based agent, gamers were highly satisfied with multimedia links. However, game information and game feedback scores were low due to the single-game mode and some technical problems in the feedback module.

Figure 17. Game satisfaction survey results

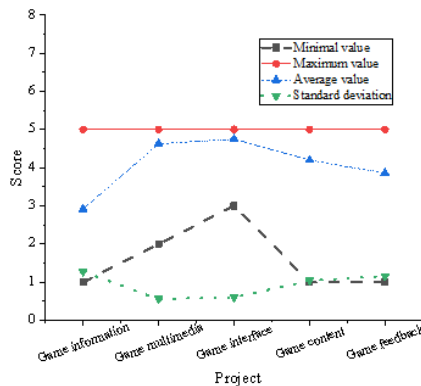


Figure 18 shows the reliability and validity analysis results of the preliminary survey. The Cronbach's  $\alpha$  coefficient of the preliminary survey was higher than 0.8, indicating good questionnaire reliability. The KMO value was much greater than 0.7, indicating that the significance level is reached, the validity of the questionnaire is good, and the formal questionnaire can be distributed. Due to the limited space, the reliability and validity results of the formal questionnaire are given here, which are higher than 0.8 and 0.7, indicating that the reliability and validity of the questionnaire are good. The average extraction variance of the questionnaire was higher than 0.6, and the composite reliability was higher than 0.8, indicating that the discriminant validity of the model is good. The variance expansion factor of the variable is below 10, indicating that the model can carry out path analysis.

Figure 18. Reliability and validity analysis results of preliminary survey

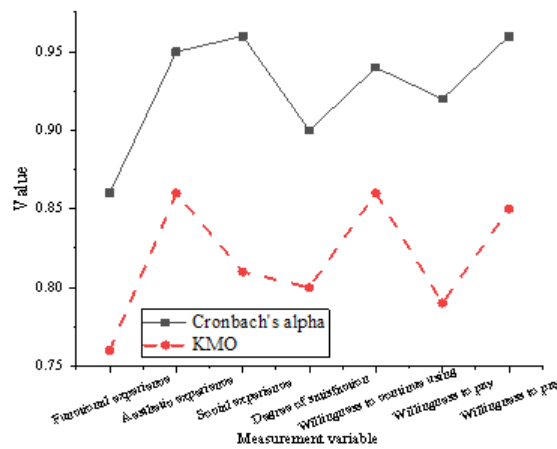


Figure 19 shows the model path test results. Figure 19 suggests that the path coefficients here are basically positive, indicating that most assumptions are true. The path coefficient of aesthetic experience and satisfaction is -0.014, indicating that this assumption is not valid. The hypotheses established are as follows. The users' willingness to pay for and continue to use mobile education games has a significant impact on the change in their learning behavior. Users' willingness to continue to use mobile education games has a significant impact on their willingness to pay, which is consistent with the conclusion reached by Goli and Vemuri (2021).

Mobile education game user satisfaction with the platform significantly impacts their willingness to continue to use a game. Mobile education game user satisfaction with the platform has a significant impact on the willingness to pay for it. The functional experience of mobile education game learning users has a significant impact on satisfaction. The social experience of mobile education game learning users has a significant impact on their satisfaction. The untenable hypothesis is that the aesthetic experience of mobile learning users has a significant impact on their satisfaction, indicating that there is no significant relationship between aesthetic experience and satisfaction.



Figure 19. Path test results of the structural model

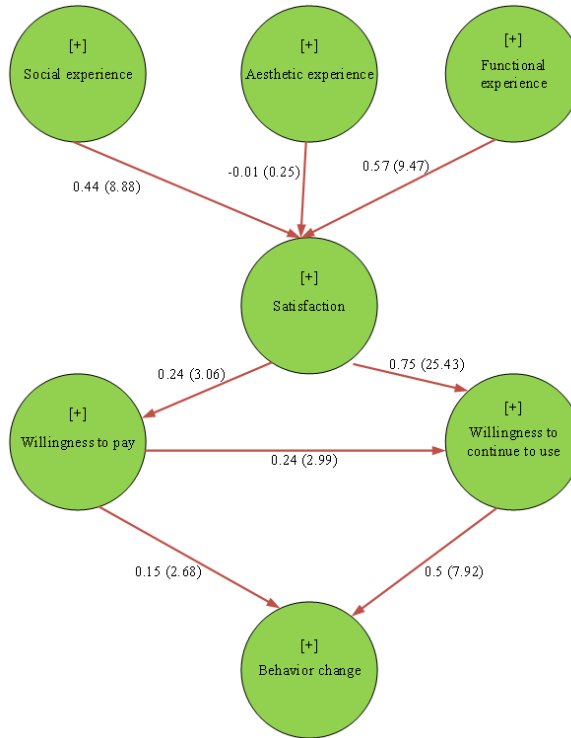
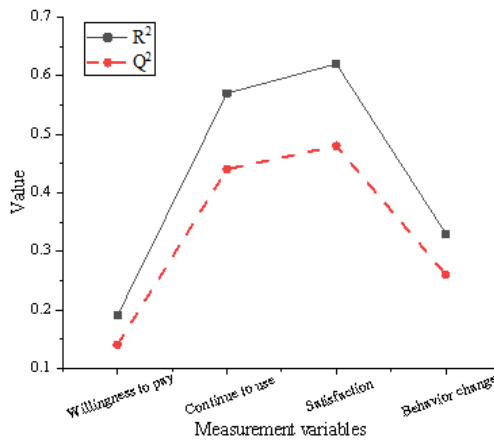


Figure 20 shows the resulting  $R^2$  and  $Q^2$  values. The  $R^2$  values of continuous use intention and satisfaction are 0.57 and 0.62, respectively, both greater than 0.5. The  $Q^2$  values of the four variables of *willingness to continue use*, *willingness to pay*, *behavior change*, and *satisfaction* were between 0.1 and 0.5, which is greater than 0, indicating that the interpretation of the model is strong and has a strong prediction correlation, which means that the model constructed is feasible.

Figure 20. Model prediction ability and stability results



The results show that the learning behavior of mobile educational game users is related to the continuous use rate of users, especially the satisfaction of users with the mobile educational game is significantly related to the continuous use intention of users. This thesis has a positive impact on the improvement of mobile educational games and provides an improvement direction. The practical research significance is to solve the low continuous utilization rate of educational game users. The research results will also correct the name of a game to a certain extent. It is generally believed that games will weaken student learning ability, but the combination of games and education can improve student learning interest. The CNN-based estimation algorithm used will eventually be applied to the design of agents, so a bridge is built between theory and practice. After further improvement, this work can be used to develop mobile educational games and school teaching. After the research conclusions are considered, game developers can shift the focus to improving user satisfaction and improving product quality. The combination of this thesis and school teaching mainly lies in the addition of educational games in school teaching to increase student interest in a class. The impact of this thesis on society lies in the further promotion of educational games and addressing learning difficulties.

## **DISCUSSION**

The final results reveal that mobile educational game learning behavior is related to user willingness to continue use. Compared with the previous literature review, the educational game design here is relatively simple because the Sudoku games are used in the game design and the research objects are primary school students. It also leads to the limited coverage of the final game players. The results of previous studies on learning behavior show that interaction among students promotes the generation of learning behavior. Although this thesis does not directly draw this conclusion, it confirms that learner willingness to continue to use mobile educational games has been strengthened due to the use of the social interaction module between learners. The influencing factors of user satisfaction for the mobile educational game include functional experience, social experience, and payment function. Yim and Byon (2018) showed that the functional experience affected game user satisfaction, which was basically consistent with the research conclusion here (Yim & Byon, 2018). For the problem of the social module in games, Zhang et al. (2021) believed that the addition of the social module positively affected user behavior, which was consistent with the research results of the social module here (Zhang et al., 2021). The results also support the purpose of this study, that is, this study can improve student interest in learning.

## **CONCLUSION**

### **Research Contribution**

With the progress of smart mobile devices, mobile educational games also begin to develop rapidly, but the user persistence rate of educational games is not high. Based on the concept of social media, this study applied an estimation algorithm based on a CNN using the World Sudoku Championship dataset to examine the relationship between learning behavior and mobile educational games. The results show that the items that significantly affect learning style are the willingness to pay and the willingness to continue use. User satisfaction with a platform significantly affects willingness to continue use, functional user experience affects satisfaction significantly, and mobile education game learning social experience affects satisfaction significantly. This lays a foundation for improving the mobile educational game experience and provides a direction for the development of educational games.

## **Limitations and Future Work**

Regarding the limitations of this study, the CNN model does not consider the memory function of the model in the design of educational game agents. Technical problems such as game simplification and feedback modules of the mobile educational game model have not been solved. The feedback module greatly affects the user experience. The selected research object is one-sided, and the sample size is small, which may lead to the typification of the conclusion.

Therefore, the follow-up research will explore the memory function of CNN and study the influence of agents on learning behavior. It will further improve the technicality of the game model. The coverage and sample size of the research object will be expanded to get a conclusion with more academic value. The impact on real life, related research, and society is as follows. This thesis provides an improvement direction for the application of educational games in life. The research value is to provide a reference for further research and development in educational games and put forward reasonable suggestions for the wide popularization of educational games in society. Finally, the valuable suggestions highlighted are that educational games should highlight product characteristics, identify user groups, improve system functions, pay attention to user experience, stimulate internal motivation, and improve users' sense of belonging.

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## **CONFLICT OF INTEREST**

All authors declare that they have no conflict of interest.

## **ETHICAL APPROVAL**

This article does not contain any studies with human participants or animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

## **AUTHOR CONTRIBUTIONS**

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

## REFERENCES

- Acquah, E. O., & Katz, H. T. (2020). Digital game-based L2 learning outcomes for primary through high-school students: A systematic literature review. *Computers & Education*, *143*, 103667. doi:10.1016/j.compedu.2019.103667
- Adeyemi, I. O., Esan, A. O., & Aleem, A. (2021). Application of gamification to library services: Awareness, perception, and readiness of academic librarians in Nigeria. *The Electronic Library*, *39*(5), 767–781. doi:10.1108/EL-05-2021-0096
- Barros, C., Carvalho, A. A., & Salgueiro, A. (2020). The effect of the serious game Tempoly on learning arithmetic polynomial operations. *Education and Information Technologies*, *25*(3), 1497–1509. doi:10.1007/s10639-019-09990-4
- Blumberg, Z., Markovits, A., & Schnoll, A. (2020). A history of America's aversion to tie games in popular team sports. *International Journal of the Sociology of Leisure*, *3*(2), 153–175. doi:10.1007/s41978-020-00053-4
- De Jonge, D., & Zhang, D. (2020). Strategic negotiations for extensive-form games. *Autonomous Agents and Multi-Agent Systems*, *34*(1), 1–41. doi:10.1007/s10458-019-09424-y
- Dubé, A. K., & Dubé, N. J. (2021). Policies to guide the adoption of educational games into classrooms. *Educational Technology Research and Development*, *69*(1), 167–171. doi:10.1007/s11423-020-09835-9
- Goli, M., & Vemuri, V. V. (2021). Users' in-game purchase intention: The effects of flow experience and satisfaction. *Journal of Electronic Commerce in Organizations*, *19*(4), 1–19. doi:10.4018/JECO.2021100101
- Griffiths, M. D., & Pontes, H. M. (2020). The future of gaming disorder research and player protection: What role should the video gaming industry and researchers play? *International Journal of Mental Health and Addiction*, *18*(3), 784–790. doi:10.1007/s11469-019-00110-4
- Harley, J. M., Poitras, E. G., Jarrell, A., Duffy, M. C., & Lajoie, S. P. (2016). Comparing virtual and location-based augmented reality mobile learning: Emotions and learning outcomes. *Educational Technology Research and Development*, *64*(3), 359–388. doi:10.1007/s11423-015-9420-7
- Havukainen, M., Laine, T. H., Martikainen, T., & Sutinen, E. (2020). A case study on co-designing digital games with older adults and children: Game elements, assets, and challenges. *The Computer Games Journal*, *9*(2), 163–188. doi:10.1007/s40869-020-00100
- Hines, E. M., Mayes, R. D., & Hines, M. R. (2021). "You are going to school": Exploring the precollege experiences of first-year black males in higher education. *Professional School Counseling*, *25*(1c). Advance online publication. doi:10.1177/2156759X211040044
- Huda, S. N., & Ramadhan, M. (2021). Designing educational game to increase environmental awareness. *International Journal of Emerging Technologies in Learning*, *16*(15), 181–193. doi:10.3991/ijet.v16i15.22661
- Huizenga, J., Admiraal, W., Ten Dam, G., & Voogt, J. (2019). Mobile game-based learning in secondary education: Students' immersion, game activities, team performance and learning outcomes. *Computers in Human Behavior*, *99*, 137–143. doi:10.1016/j.chb.2019.05.020
- Jackson, C. L., & Jackson, G. T. (2021). Let's play! The use of educational games as an intervention tool for autism spectrum disorder. *Education and Technology Support for Children and Young Adults With ASD and Learning Disabilities*, 294–314. 10.4018/978-1-7998-7053-1.ch015
- Jung, C. W. (2020). The role of game genres and gamers' communication networks in perceived learning. *Palgrave Communications*, *6*(1), 1–8. doi:10.1057/s41599-020-0439-y
- Leditzky, F., Alhejji, M. A., Levin, J., & Smith, G. (2020). Playing games with multiple access channels. *Nature Communications*, *11*(1), 1–5. doi:10.1038/s41467-020-15240
- Liu, X., Xie, M., Wen, X., Chen, R., Ge, Y., Duffield, N., & Wang, N. (2020). Micro- and macro-level churn analysis of large-scale mobile games. *Knowledge and Information Systems*, *62*(4), 1465–1496. doi:10.1007/s10115-019-01394-7

- Marston, H. R., & del Carmen Miranda Duro, M. (2020). Revisiting the twentieth century through the lens of Generation X and digital games: A scoping review. *The Computer Games Journal*, 9(2), 127–161. doi:10.1007/s40869-020-00099-0
- Nizam, D. N. M., & Law, E. L. C. (2021). Derivation of young children's interaction strategies with digital educational games from gaze sequences analysis. *International Journal of Human-Computer Studies*, 146, 102558. doi:10.1016/j.ijhcs.2020.102558
- Park, C. H., Kim, H., Lee, J., Ahn, G., Youn, M., & Youn, B. D. (2021). A feature inherited hierarchical convolutional neural network (FI-HCNN) for motor fault severity estimation using stator current signals. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 8(4), 1253–1266. doi:10.1007/s40684-020-00279-3
- Rahimi, S., Shute, V., Kuba, R., Dai, C. P., Yang, X., Smith, G., & Fernández, C. A. (2021). The use and effects of incentive systems on learning and performance in educational games. *Computers & Education*, 165, 104135. doi:10.1016/j.compedu.2021.104135
- Rheu, M., Shin, J. Y., Peng, W., & Huh-Yoo, J. (2021). Systematic review: Trust-building factors and implications for conversational agent design. *International Journal of Human-Computer Interaction*, 37(1), 81–96. doi:10.1080/10447318.2020.1807710
- Ruipérez-Valiente, J. A., Gomez, M. J., Martínez, P. A., & Kim, Y. J. (2021). Ideating and developing a visualization dashboard to support teachers using educational games in the classroom. *IEEE Access: Practical Innovations, Open Solutions*, 9, 83467–83481. doi:10.1109/ACCESS.2021.3086703
- Schmidt, A., Geringswald, F., Sharifian, F., & Pollmann, S. (2020). Not scene learning, but attentional processing is superior in team sport athletes and action video game players. *Psychological Research*, 84(4), 1028–1038. doi:10.1007/s00426-018-1105-5 PMID:30294749
- Shi, J., Zhou, W., & Wang, Y. (2020). A preliminary study on the design of mobile educational game applied to pharmacology teaching. *2020 International Conference on Artificial Intelligence and Education*, 47–51. doi:10.1109/ICAIE50891.2020.00019
- Shute, V., Rahimi, S., Smith, G., Ke, F., Almond, R., Dai, C. P., & Sun, C. (2021). Maximizing learning without sacrificing the fun: Stealth assessment, adaptivity and learning supports in educational games. *Journal of Computer Assisted Learning*, 37(1), 127–141. doi:10.1111/jcal.12473
- Skowronski, M., Busching, R., & Krahé, B. (2021). The effects of sexualized video game characters and character personalization on women's self-objectification and body satisfaction. *Journal of Experimental Social Psychology*, 92, 104051. doi:10.1016/j.jesp.2020.104051
- Talib, M. A., Majzoub, S., Nasir, Q., & Jamal, D. (2021). A systematic literature review on hardware implementation of artificial intelligence algorithms. *The Journal of Supercomputing*, 77(2), 1897–1938. doi:10.1007/s11227-020-03325-8
- Triantoro, T., Gopal, R., Benbunan-Fich, R., & Lang, G. (2020). Personality and games: Enhancing online surveys through gamification. *Information Technology Management*, 21(3), 169–178. doi:10.1007/s10799-020-00314-4
- Vermeiren, S., Duchatelet, D., & Gijbels, D. (2022). Assessing students' self-efficacy for negotiating during a role-play simulation of political decision-making. Taking student characteristics and simulation features into account. *Studies in Educational Evaluation*, 72, . <ALIGNMENT.qj></ALIGNMENT>101124
- Wang, Z., & Han, F. (2021). Developing English language learners' oral production with a digital game-based mobile application. *PLoS One*, 16(1), e0232671. doi:10.1371/journal.pone.0232671 PMID:33400694
- Xiong, Z., Liu, Q., & Huang, X. (2022). The influence of digital educational games on preschool Children's creative thinking. *Computers and Education*, 189, 104578.
- Yim, B. H., & Byon, K. K. (2018). The influence of emotions on game and service satisfaction and behavioral intention in winning and losing situations: Moderating effect of identification with the team. *Sport Marketing Quarterly*, 27(2), 93–107. doi:10.32731/SMQ.272.062018.03
- Yu, Z., Gao, M., & Wang, L. (2021). The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research*, 59(3), 522–546. doi:10.1177/0735633120969214

Zenggang, X., Mingyang, Z., Xuemin, Z., Sanyuan, Z., Fang, X., Xiaochao, Z., Yunyun, W., & Xiang, L. (2022). Social similarity routing algorithm based on socially aware networks in the big data environment. *Journal of Signal Processing Systems for Signal, Image, and Video Technology*, 2022, 1–15. doi:10.1007/s11265-022-01790-3

Zenggang, X., Xiang, L., Xueming, Z., Sanyuan, Z., Fang, X., Xiaochao, Z., Yuanyun, W., & Mingyang, Z. (2022). A service pricing-based two-stage incentive algorithm for socially aware networks. *Journal of Signal Processing Systems for Signal, Image, and Video Technology*, 2022, 1–16. Advance online publication. doi:10.1007/s11265-022-01768-1

Zhai, X., Dong, Y., & Yuan, J. (2018). Investigating learners' technology engagement-a perspective from ubiquitous game-based learning in smart campus. *IEEE Access: Practical Innovations, Open Solutions*, 6, 10279–10287. doi:10.1109/ACCESS.2018.2805758

Zhang, C., Hauge, J. B., Härenstam, K. P., & Meijer, S. (2021). Game experience and learning effects of a scoring-based mechanic for logistical aspects of pediatric emergency medicine: Development and feasibility study. *JMIR Serious Games*, 9(1), e21988. doi:10.2196/21988 PMID:33704081

Zheng, W., Liu, X., Ni, X., Yin, L., & Yang, B. (2021). Improving visual reasoning through semantic representation. *IEEE Access: Practical Innovations, Open Solutions*, 9, 91476–91486. doi:10.1109/ACCESS.2021.3074937

Zheng, W., Liu, X., & Yin, L. (2021a). Sentence representation method based on multi-layer semantic network. *Applied Sciences (Basel, Switzerland)*, 11(3), 1316. doi:10.3390/app11031316

Zheng, W., Yin, L., Chen, X., Ma, Z., Liu, S., & Yang, B. (2021b). Knowledge base graph embedding module design for visual question answering model. *Pattern Recognition*, 120, 108153. doi:10.1016/j.patcog.2021.108153

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