Digital Game Based Learning in Computer Science Education: A Card Sorting Game

Preetika Chandel, Deepika Dutta, Prikshit Tekta and Kamlesh Dutta
Department of CSE, NIT Hamirpur, H.P.
E-mail: preetika.nith@gmail.com; deepika27dutta@gmail.com; prikshittekta@gmail.com; kd@nith.ac.in

ABSTRACT

Digital Game Based Learning describes an approach to teaching, where students explore relevant aspect of games in a learning context designed by teachers. Traditional passive teaching approaches limits us to narrow procedures, and then evaluate us on our memory of what we were told, but within an effective gaming environment, we work towards a goal, select actions and experience the consequences of those actions along the way and practice the right way to do things. The changing trends in Computer Science education system presents the need to introduce substantial changes in the current teaching-learning patterns and therefore, it becomes imperative that the approaches used by us are also modified along with time. This paper aims to propose the emerging need to promote Digital Game Based Learning as games provide the understanding of deeper, more abstract principles which prepare us to perform consistently and efficiently, even in new and unexpected situations. The paper studies the effectiveness of digital game based learning through the implementation of a card sorting game. The game has been specifically designed to aid the learning process of students and the results have been compared with theoretical learning, which further strengthen the utility of Digital Game Based Learning.

Keywords: Digital Game Based Learning, Passive Teaching Approach, Computer Science Education.

INTRODUCTION

The increasing research in the field of computer games emphasizes the need to bring modifications in traditional teaching-learning methods. The idea that Computer games can be used to engage, challenge and motivate learners is being given importance. Games tend to provide clear, well defined goals for success. They act as a great source to motivate players to earn points and obtain top positions on leaderboards. A steady work flow occurs when one gets involved in problem-solving, strategy building or simply the desire to win. Games ensures the existence of opportunities to adjust and refine player's performance since they offer continual and immediate feedback. The repetitive nature of games ensures perfection and brings mastery in any field.

Computer science has immense impact on many aspects of modern life, and its importance is increasing in the future. Therefore, it is essential that the CS concepts are studied and understood in depth. Game based learning approach which deals with incorporating games with learning along with the general teaching trend tend to make the teaching and learning process highly interactive

and effective. Hence, they should be introduced in the subdomains of Computer Science education such as computer programming, learning algorithms.

RELATED WORK

A study by Marina Papastergiou[1] assessed the learning effectiveness and motivational appeal of a computer game for learning computer memory concepts, which was designed according to the curricular objectives and the subject matter of the Greek high school Computer Science (CS) curriculum, as compared to a similar application, encompassing identical learning objectives and content but lacking the gaming aspect. Young people's intrinsic motivation towards games contrasts with their often noted lack of interest in curricular contents [2]. Oblinger D. [3] observed that appropriate games constitute powerful learning environment as they can support: (a) multi-sensory, active learning, (b) use of precious knowledge in order to advance. (c) self-correction by providing immediate feedback on student actions, (d) self assessment by exploiting the scoring mechanisms, (e) acts as social environment for community of players. In the study conducted by Kebritcki and Hirumi [4] the results indicated a significant improvement of achievements of pupils who played computer games both in ordinary classrooms and computer labs. Prior knowledge, skills did not have a significant role in achievements or motivation. It was observed that computer games have been effective in raising achievement levels of both children and adults in various areas of knowledge such as Science, Math, Language and Computer Science, where specific learning objectives can easily be stated [5]. Encouraging results have also been pointed from the use of educational digital card games for the learning of various subjects such as Physics [6], Language[7], etc.

A number of studies related to the use of computer card games in Computer Science (CS) education have provided the evidence of effective learning. Constructivist learning can be attained by appropriately designed card games[8], which provides students with opportunities to develop their cognitive skills. Specific card games can help students retain, develop and improve various basic math and logical skills. The successful use of card games in the learning of various curriculum subjects such as Chemistry, Language and Financial studies have also been recorded. computer games play a vital role in youngster's lives [9]. A card game designed by Baker *et al.* [10] helped learners gain some experience of software engineering. A physical competitive card game named "Problems and Programmers (PnP)" has also been constructed for software engineering [11], the rules and methods of which are based on the Waterfall model. Kim *et al.* [12] presented a Smalltalk Card Game which was aimed at learning about object-oriented thinking and learning. A card game about Rapid Application Development was designed in order to assist learners in study system analysis and design [13]. Mitsuhara *et al.* [14] reported the involvement of students in real world game, where digital cards displaying BNs were used to provide students with information. Inspired by the effectiveness of card games in various disciplines, the work carried out in this paper presents a card based sorting game to facilitate digital game based learning.

DIGITAL GAME ADOPTION IN CS COURSE CURRICULUM

The CS curriculum taught in various engineering institutions offers several avenues for the adoption of digital games for the purpose of teaching and thereby making learning process effective and more interesting. A preliminary survey was conducted on the students of CS department at NIT

Hamirpur wherein the current teaching methods being employed were compared. It was observed that the teaching course consisted of traditional passive teaching-learning practices supplemented with some technologically supported tools [15]. The questionnaire summarized in Table 1 constituted the survey.

Table 1: Survey on DGBL

Question	Parameters				
How often did students play digital games	Sometimes	Very much	Never		
Type of digital games students liked	Immense role playing	Puzzle based	Short play	Board	
Learn to code by playing digital games	5	4	3	2	1
Opinion for coding websites	Very useful	Satisfactory	Complete waste of time		
Response to current teaching techniques	Satisfied	Boring	Effective	Very boring	Very effective
Current teaching trends	Combination of both	Theoretical	Practical		
Response to e-learning	Yes	No			
Integrating digital games into teaching and learning	Individual/group/class	Extra credit	Competition	Homework	

The questionnaire covered wide range of issues. These issues were posed as questions as mentioned below:

1. How often the students play digital games: The response indicated that the students played digital games at moderate amount of times.
2. Type of digital game students liked: The response shows that a majority of B.Tech Final Year students preferred immense role playing games followed by the puzzle games which check their problem solving abilities.
3. Learn to code by playing digital games: The majority students were of the opinion that if they had to give marks to the approach of learning to code by playing games then it deserved the maximum. This shows that the students feel that this is a viable approach and hence must be promoted more to help the students gain more clarity.
4. Opinion for coding websites: The response indicates that most of the students felt that coding websites were very useful in helping them improve their coding skills and not exactly a waste of time.
5. Response to current teaching techniques: The response tells that the majority students were merely satisfied with the current teaching approach which provides a huge scope of improvement which makes the teaching and learning process more efficient and effective.
6. Current teaching trend: A large segment of students felt that the present approach was a combination of both theoretical and practical approaches, followed by theoretical.
7. Response to e-Learning: The survey response showed an affirmative response towards e- Learning.
8. How integration of digital games should be done: The students felt that the integration of the games should be done as individual/ group/ class assignments preferably.

From the survey, it was observed that a fair segment emphasized the need to switch to a more practical and friendly teaching approach and agreed that the learning rate will increase by playing subject related games as Computer games provide a compelling context for their learning. Digital Game Based Learning will offer unique structure to compliment traditional strategies, spark innovative thinking and provide diversity in teaching methods.

GAME DESCRIPTION

Taking into account the issues of mundane teaching practices in Computer Science, digital game based learning is a stepping stone towards improving the general trend of teaching and learning. The idea of introducing games in Computer Science education has worked as a constant motivation which led to the development of a web based, card sorting game. Easy and readily accessible game controls attracts the user's attention that keep him focused on the game. The depiction of a highly motivational and interesting virtual world will help in creating a conducive environment for learning.

The major subjects that forms the basis of CS education are Data Structures [16] and Design and Analysis of Algorithms [17]. Students generally find the sorting algorithms used in these confusing and difficult to understand. Therefore, arises the need of devising an efficient solution to teach sorting algorithms to the students. The game presented in this paper is primarily designed for the students who intend to learn sorting algorithms. Such a well-structured and interactive game will help them grasp the concepts in a better and coherent manner.

All the basic sorting algorithms namely selection, insert, bubble, shell, merge, heap, quick and bucket sort have been included in the game. Each sorting algorithm is provided with a manual so that before commencing the game the user gets the very basic understanding of the selected algorithm. The selection of the algorithms has been made keeping in mind the very basic and commonly used algorithms in computational work and the need for learning them. Being able to sort the cards according to the selected algorithm, will help the user to understand at each step/move he makes.

The digital game presented in this paper, allows the users to learn the sorting algorithms by actually sorting a deck of cards in following steps -

1. After selecting the sorting algorithm user is provided with the algorithm manual which highlights the steps followed in the sorting algorithm.
2. After understanding the algorithm the user can apply the algorithm by actually sorting a deck of randomly placed cards on the screen.
3. The movement of the cards will be triggered by the drag and drop of the cursor.
4. Any move made by the user will shuffle the cards if the move is valid according the algorithm that the user is trying to implement,
5. Whereas any move that is not valid according to the algorithm being implemented will show no movement of the cards and will show an indication to the user of wrong move.
6. After all the valid moves are made the final result will be the sorted deck of the cards.

The idea behind the game can be represented in the form of a flow chart as shown in Figure 1.

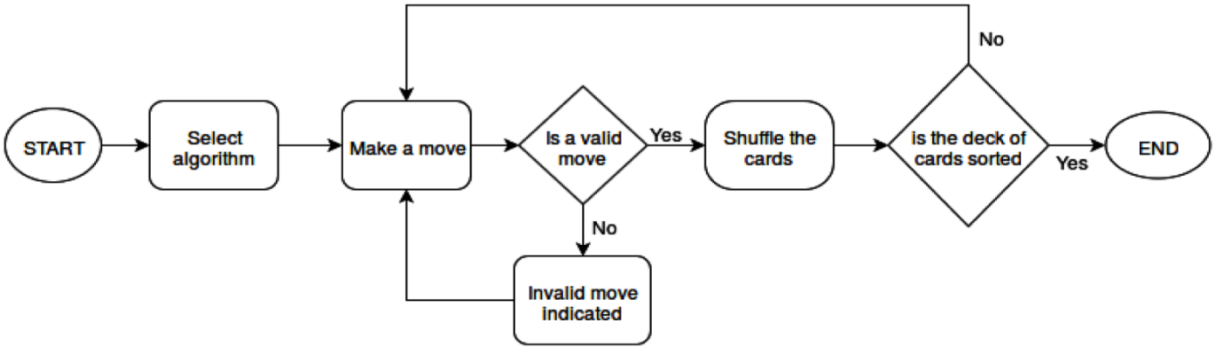

Fig. 1: Card Sorting Game Flow Chart

Game Structure

The above mentioned web based card sorting game has a simplified and minimal structure. Anyone with no prior knowledge of the context can try their hands on this game.

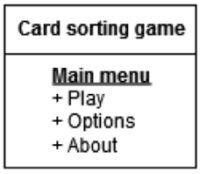

Fig. 2: Main Menu Options

A comprehensive and less clustered main menu structure as shown in Figure 2 adds to the effectiveness of the gameplay. Moreover the game is structured with clear learning objectives at each step. After opting to play, the user has to select the algorithm that he wishes to learn from the Select Algorithm menu as shown in Figure 3.

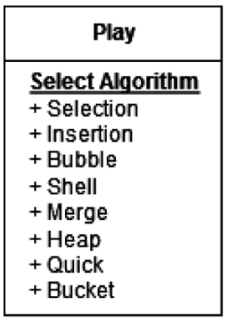

Fig. 3: Algorithm Selection Menu

After the user selects the algorithm to learn, an algorithm manual will be displayed on screen so that the user gets the basic idea of the algorithm flow and after the user understands it, few randomly placed cards will appear on screen which the user has to sort. As stated earlier only the valid moves will result in shuffling/movement of the cards whereas an invalid move will show an indication of a wrong move.

Levels

Based on the expertise of the user, he can set the difficulty level of the game ranging from beginner to an expert level. Fig. 4 shows the structure of the options menu with preferences for each session. The levels merely differ in certain parameters as stated below -

1. Availability of algorithm manual, that won't be accessible in expert mode
2. Placement of the shuffled cards which in an expert mode will be strategic
3. The number of cards to sort, which will increase at each level.

Fig. 4: Options Menu

GAME PLAY EXPERIENCE STUDY

This study was conducted in three stages, namely: A. Theoretical class learning, B. The game play as a learning experiment, C. Post-test analysis.

A. Theoretical class learning for Group A students

A set of 20 Computer Science students (Group A) studying in B.Tech, second year at NIT Hamirpur were given a lecture about the sorting algorithms in a theoretical class. The course covered all the algorithms that had been included in the game whose design has been explained above. After the completion of the class the students were quizzed on the algorithms and their results were stored, followed by a short survey based on their experience.

B. Game play

Another set of 20 students (Group B) of the same class were made to play the game which contained the detailed explanation of the algorithms followed by the practical implementation through gaming exercise. After the successful completion of the game the students were made to take the same quiz as was taken by the theoretical class students, followed by the same short survey.

C. Post-test analysis

A comparison was made of the test scores of the two sets and the survey was studied. The following inferences were drawn:

1. The average test scores of the students of Group B were relatively higher than Group A students.
2. Group B students response to the survey indicated that they were very comfortable with the gaming exercise. Also, the game succeeded in creating interest of the user.

The test score plot of the two groups is as follows along with their average test scores:

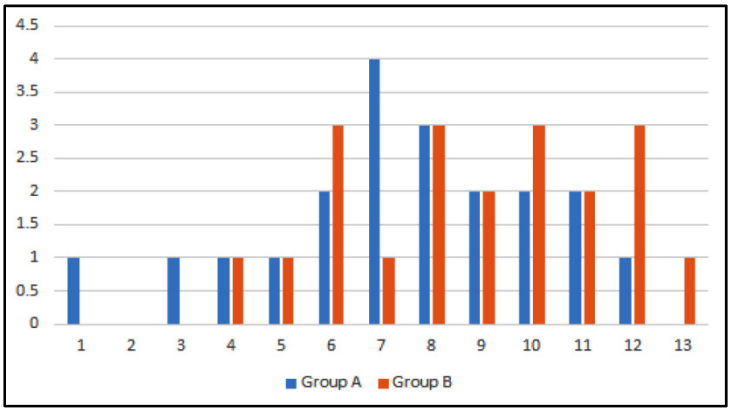

Fig. 5: Distributed Graph of Test Scores of Group A and Group B

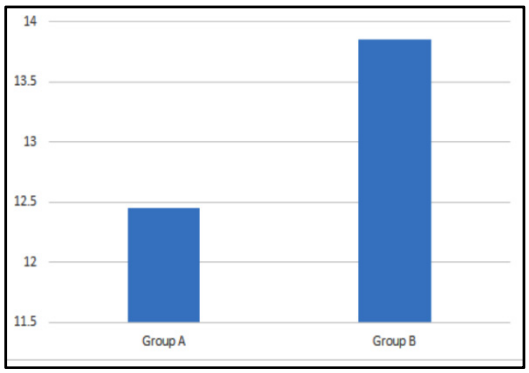

Fig. 6: Average Test Scores of Group A and Group B

The average test scores of Group B which are higher than Group A as seen in Fig. 5 and Figure 6 indicated that the practical game based learning approach used with Group B yields better results as compared to theoretical learning approach. The survey questions that were asked and their responses are as follows:

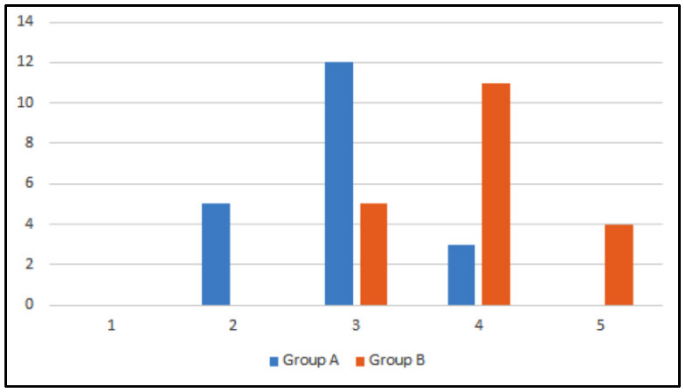

Fig. 7: How Clear are the Algorithms on a Scale of 1 to 5

As seen in Figure 7 the students in Group B gained more clarity on the concepts related to algorithms relative to that of Group A. Thus, it can be inferred that digital game based learning approach leads to better conceptual clarity and understanding of the subjects.

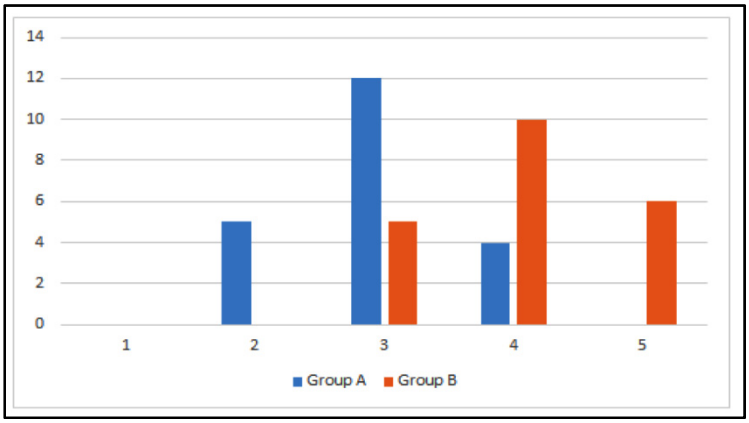

Fig. 8: On a Scale of 1 to 5, How much did You Enjoy the Session

In Figure 8 it was seen that the students of Group B who attended the game class have enjoyed the session more than the students of Group A, who attended the theoretical class. Besides providing better conceptual clarity, game based play also creates more interest in the topics like sorting algorithms which may be perceived as boring and confusing by the students.

CONCLUSION

The main objective of this paper was to promote and establish the importance of game based learning in the CS curriculum. It is evident that using advanced techniques involving the idea to use games to teach will help increase the learning skills of students. The results of the card sorting game implemented here, further highlights the fact that digital game based learning provides a better platform for interactive learning. Also, the students feel that such an approach helps them to gain better clarity of the concepts. Through fancy games, students tend to develop interest and therefore, are expected to learn more quickly and think more creatively. Hence, it is the need of hour to promote digital games for the purpose of effective learning in our present CS education system.

REFERENCES

[1] Papastergiou M., "Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation," Science Direct,vol. 52, Issue 1, January 2009, Pages 112, 2009.16

[2] Prensky, M., "Digital game-based learning," ACM Computers in Entertainment, 1(1), 1–4 2003 [3]Oblinger, D., "The next generation of educational engagement," Journal of Interactive Media in Education, 2004 (8), 1–18. 2004

[4] Kebritchi, M., Hirumi, A., "Examining the pedagogical foundations of modern educational computer games, Computers and Education," Volume 51, Issue 4, December 2008

[5] Rajaravivarma, R.,"A games-based approach for teaching the introductory programming course," Inroads ACM SIGCSE Bulletin, 37(4), 98–102 2005

[6] Smith, D. R. and Muhro, E., "Educational card games," Physics Education, 44(5), 479–483 2009

[7] McGraw, I., Yoshimoto, B. and Seneff, S. "Speech-enabled card games for incidental vocabulary acquisition in a foreign language," Speech Communication, 51, 1006–1023, 2009.

[8] Kamii, C. and DeVries, R., "Group games in early education: Implications of Piaget's theory," Washington: National Association for the Education of Young Children, 1980

[9] Kirriemuir, J. and McFarlane, C.A. REPORT 8: Literature Review in Games and Learning, 2004 [10]Baker, A., Navarro, E. O. and Van Der Hoek, A., "An experimental card game for teaching software engineering processes," Journal of Systems and Software, 75,3–16,2005

[11] Carrington, D., Baker, A. and van der Hoek, A., "It's all in the Game: Teaching software process concepts," In Proceedings 35th Annual Conference Frontiers in Education, FIE, pp. F4G-13–F4G-18, 2005

[12] Kim, S. B., Choi, S. K., Jang, H. S., Kwon, D. Y., Yeum, Y. C. and Lee, W.G, "Smalltalk card game for learning object-oriented thinking in an evolutionary way, In OOPSLA, Portland, Oregon, USA, pp.683–684, 2006

[13] Chang, W.-C., Chen, Y.-L. and Lee, T.-P., "Computer assisted learning with card game in system design concept," In E. W. C. Leung *et al.* (Eds.),Advances in blended learning, 2008, LNCS, 5328 (pp. 93–101), Berlin: Springer-Verlag 2008

[14] Mitsuhara , H., Ogata, H., Kanenishi, K. and Yano, Y.,"Do children understand BNs by electric card game?,"Proceedings of DIGITEL 2007: First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning 2007, pp. 191–193 2007[16] S. Erhel, E.Jamet,"Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness," March 2013

[15] Dutta K., Chandel P., Dutta D. and Tekta P., "Digital Game Based Learning In Computer Science Education," in National Conference - Career Point University, 2016

[16] Seymour Lipschutz, "Data Structures," Schaum's Outline of Data Structure. McGraw-Hill, Inc. New York, NY, USA ©1987

[17] T.H. Cormen, C.E. Leiserson, R.L. Rivest and C. Stein, "Introduction to Algorithms," MIT Press Cambridge, 2009.

Preetika Chandel

Department of CSE, NIT Hamirpur, H.P.

Preetika Chandel is a final year B.Tech undergraduate student of Computer Science and Engineering Department at National Institute of Technology, Hamirpur, H.P. Born and raised in Shimla, she is fond of nature's beauty and has a strong affection for hills. From high school only she was passionate about programming technologies and strived to gain in depth knowledge of the concerned subjects. She has showed extreme determination in working on projects related to website developments, Artificial Intelligence, Natural Language processing. She has served as an intern at Defence Research and Development Organisation, Delhi where she realised her inclination towards research work in CS field. Being an active enthusiast of graphics design and video editing, she has worked as a convenor of the college animation club. Also, she has held various important positions at departmental level societies. In her free time, she enjoys travelling, reading books and technophilic blogs.