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Can Games Based Learning Enhance Learning of Chemistry?

Kamalika Banerjee, Indira Gandhi National Open University
kamalika@ignou.ac.in

Introduction

The words gamification and game-based learning are of course not the same. Game-based learning is in short, learning through games. Using games in the classroom transfers the teaching-learning situation from teacher-centric to student-centric. It is disheartening to note that many a times it is noted that the fear for chemistry amongst the students arises due to the lack of domain-specific didactics amongst the chemistry teachers especially those in higher education. This in turn does not facilitate learning of chemistry. 'Passive Diffusion Model of Knowledge Transfer' does not lead to meaningful learning as only knowledge is transferred. Often the chemistry teachers overload the working memory of the students which lead to inefficient learning. Thereby the students are unable to process the huge amount of apparently unrelated information. Moreover there should be connections between theory and practical whereas it is not. Rote learning facts and mechanically going through the practical sessions lead to enhancement of fear for chemistry and not understanding the subject.

Chemistry deals with explaining the properties and transformations of substances at the sub-microscopic level. Molecular models are used in chemistry as an important learning tool. But the students have difficulty in differentiating between models and real things and therefore the models may not serve their purpose(Grosslight et al., 1991). But, in the case of computer visualizations different models, side-by-side can be seen, to help one develop the cognitive side of learning.

Now the point to ponder is it's 2019, still why do 21st century skills matter? There is a paradigm shift in the teaching-learning process from teacher-centred to student-centred education. Instead of relying on textbooks and teacher direction, these students had to think critically about unfolding events, collaborate with peers and adults, and make creative use of digital tools to communicate their ideas. The aim of all this is to enable students "to make meaningful contributions to the world."(Kaya, 2010, Sung & Hwang, 2013).

It is obvious that games improve the development of the mind. Students who may feel that they are not comfortable in maths/science may on the other hand be enthusiastic with GBSL even though it is a difficult game. Constructivist theory of learning is the basis of GBSL that is Games Based Science Learning (Driver & Oldham, 1986). Properly designed educational games help in active learning and promote collaborative and social skills of students (Costa, 2007; Pivec & Dziabenko, 2004). GBSL also helps students to find out the required information through self-study (Oakman, 2016).

The review on GBSL took the studies published from 2000 to 2011 (Li and Tsai, 2013). In this review, 31 articles through Web of Science and SCOPUS databases were taken. Cognitivism, constructivism, the socio-cultural perspective, and enactivism, were the four theoretical foundations which were used in the theories and models of these studies. Research on GBSL shows that most of the digital games were utilized to promote scientific knowledge/concept learning, while less than one-third were implemented to facilitate the students' problem-solving skills. There has been suggestion to utilise GBSL research to improve the affective and socio-contextual aspects of science learning. Thus science learning can be improved by removing the gap between real and virtual worlds, to promote collaborative problem-solving, to provide affective learning environments (Betts, 2015). The literature reviewed was then categorized based on the coding framework and presented with frequencies along with detailed descriptions. Egenfeldt-Nielsen (2006) mentioned that varied learning aspects will be stressed in digital games when the learning perspectives have variety (e.g., cognitivism and socio-cultural approach). In this review paper, the theoretical foundations and learning foci of each study were categorized and their possibilities to improve learning were explored. For example, as researchers adopted cognitivist learning approach, their learning foci were on scientific knowledge/concept learning (Johnson and Mayer 2010), scientific processes (Spires et al. 2011), problem-solving (Moreno and Mayer 2005) etc. There are some researchers who employed socio-cultural perspective emphasized scientific knowledge/concept learning (Johnson and Mayer 2010) and scientific processes (Spires et al. 2011). In certain cases like Wrzesien and Raya (2010), Kolb's experiential learning theory and Gardner's Theory of Multiple Intelligence in game design were used directly.

Some other educationists like Honey and Hilton (2011) argued that game-based learning could be part of a new approach to science education in which 'teachers spark students' interest by engaging them in investigations,

helping them to develop understanding of both science concepts and science processes while maintaining motivation for science learning. Thus it was found that there is an extensive literature on GBSL involving chemistry learning.

Methodology

GBL i.e. Games Based Learning in chemistry from literature was searched through Google and the papers were selected and analysis was done. In this review paper which was the one found most useful (Li and Tsai, 2013), the Web of Science and SCOPUS database were used to search for GBL (chemistry) in research articles published from 2000 to 2011. Only the journals which are peer-reviewed were taken so that one can rely on its quality. English was the language chosen for the papers as the author was only comfortable in it. The search of the literature was carried out in January 2012. The reviewed research papers were identified through the following procedures. The keywords for GBSL were Games based learning in Chemistry. The keyword search resulted in the articles for further selection. The papers from journals were selected which had (1) specific digital games on chemistry (2) empirical evaluations or descriptions of students' learning process or outcomes and (4) full text of the article (hard/soft copy). Specially papers were taken where GBL in chemistry proved to enhance learning in chemistry.

Results and Discussions

While trying to deal with students of chemistry and being concerned with the fear of chemistry that most of them have, the author tried to find out the chemistry related games in the internet. Thereafter it was tried to find out details of work in similar area especially the ones in which Games Based Learning was developed. Some of them are discussed below.

- http://funbasedlearning.com/default.htm
  It involved Element Quiz where one can learn element names, facts and symbols, Classic Chembalancer for balancing chemical equations and so on.
- https://theardentteacher.com/2015/01/02/chemistry-games/
  Project Based Learning with Chemistry Games by the Ardent teacher was there.
- https://www.geniusgames.org/collections/science-based-tabletop-games has the Science games, card games, & board games
- https://www.edutopia.org/made-with-play-game-based-learning-resources
- https://www.learn4good.com/games/educational-learning-activities/chemistrygame.htm
- Free Chemistry-based Game to Play Online – Chemikul
- https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/chemistry-games.html

It was found that much work has been done with Periodic Tables. http://www.rsc.org/learn-chemistry/resource/res00001113/interactive-periodic-table-game?cmpid=CMP00002097 is the link to an interactive game to help students learn and consolidate knowledge and understanding of the periodic table. Also, https://www.sheppardsoftware.com/Elementsgames.htm consist of online games, where one can learn about the periodic table, chemistry, the elements and more with these free online quizzes and games. Elemental Periodical and Groupica (Bayir, 2014) are card games and Compoundica is a board game. It was found to be entertaining way for chemistry learning. The work of Sevcik et al, 2008 where educational card game was designed to help students understand and not learn by rote.

Carney (2015) has developed a deck of cards and a card game (a variation of rummy) which reviews knowledge of functional groups and reaction types thereby synthesizing target molecules. The studies which have been conducted to find out the use of different types of games for learning are not giving any straight-forward conclusions. (Kreijins, Kirschner & Jochems, 2003: Prensky, 2001). Well, design and studying educational games is regarded as a multifaceted process. Although, the educators are generally agreeing on the fact that games are the perfect for influential learning (Royle 2008: Squire, 2005) studies have been done by investigating students pre- and post test learning in the experimental and control groups. Properly used, games can be useful tool in the learning of chemistry concepts (Gee, 2005: Bolinggi, 2009; Chua, 2005).

A special mention must be made made in the paper (Antonio et al, 2016) "A Game-Based Approach To Learning the Idea of Chemical Elements and Their Periodic Classification". In this paper, the characteristics and results of a teaching unit based on the use of educational games to learn the idea of chemical elements and their periodic classification in secondary education were analyzed. Results analysed indicated that two groups of students, one that were taught with the teaching unit with games and another in the control group, who followed a traditionally taught program were taken. The former achieved statistically better final results. Finally, this research has opened vistas for task involving play (TIP), a novel type of educational resource that can be defined as intermediate between play and game scenarios. These may be created by the students too, thereby creating scope for active learning.

The game Picture Chem was designed (Kavak & Yamak, 2016) to design student-centred laboratory activities, to help students learn the names & functions of common chemistry laboratory equipment. ChemMend (Martí-Centelles & Rubio-Magnieto, 2014) was designed as a new chemical card game that enables students to get a grasp over the periods/groups of the periodic table. ESI (Educational Set of Ions), a card game aimed to teach names and formulae of anions and cations. It had set the rules of the game and at the end of the evaluation of the game and at the end, the evaluation of the game result was done. It was done in German and French languages too (Yenikalayci et al, 2017).

A Sticky Note on Forehead Game (O'Halloran, 2017) was a game developed to teach students the classes of organic compounds based on the functional groups in organic chemistry. Spires et al. (2011) used narrative-centered learning approach which utilized the storyline and dialogues to create immersive learning situations. Performance-Play-Dialog (PPD) model of GBL (Chee, Y.S. & Tan, K.C.D. (2012) is another notable model for GBL. Here the aim was to design and develop an educational game for 13-14 year olds and facilitate inquiry-based learning of chemistry. At the play-level of this GBSL, the players are trapped in the underground chemistry lab. In this process, students not only learn about chemistry but develop their identity as chemists.

In the paper "Chemistry games in the classroom: A Pilot Study" by Stojanovska M. et al (2018), GBSL on ionic bonding was implemented amongst students and teachers. It was analysed that GBSL for chemistry classroom helped promote active learning and help them develop skills to solve problems. In the paper from Australia a web-based learning tool to visualize Enzyme Linked Immunosorbent Assays (ELISAs) were developed in the digital laboratory. This may be considered as applied chemistry games. Shudayfat et al (2015) have presented the concept, implementation and experimentation of a 3D MMO (Massively Multiplayer Online) educational game. It was designed for studying chemistry in an interactive way. It has shown a positive impact on chemistry learning. pH puzzles, chemical reactions were part of the virtual gaming. Element Cycles (Pippins et al, 2011) are board games to reinforce the concepts of biogeochemical cycles.

Conclusions

It has been seen that playing games facilitated active learning, concentration and take the help of trial and error method. A well developed education game not only improves learning in the form of edutainment, but also promote interaction between peers. Traditional classrooms are inactive. Findings show that games are influential in the learning of abstract concepts, are enjoyable, and help the learners to benefit from the experiences of their peers.

It is suggested that chemistry instructors can integrate games in their teaching pedagogy. This has the potential of moving towards a meaningful learning. It is of course very important as to how games are used so that they enhance learning in chemistry.

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