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Designing a 3D Educational Game Integrated with Situated Learning and Multiple Scaffolding for Organic Chemistry Learning

Cheng-Tai LI, Jia-Wei YAN, Huei-Tse HOU*
Graduate Institute of Applied Science and Technology
Mini Educational Game Development Group,
National Taiwan University of Science and Technology, Taiwan
*hthou@mail.ntust.edu.tw

Abstract: Computer-assisted chemistry learning is an innovative teaching approach to assist chemistry courses especially in organic compound learning units including abstract concept of compound structure and the chemical reaction through repeated experiment. Digital educational game integrated with game context and multiple scaffolding for organic chemistry may help learners acquire knowledge and self-evaluate their learning performance via the scaffolding guidance and context exploration. The aim of this study is to develop a 3D educational game "*Through the Organic Adventure* ©" with organic compound knowledge. The study conducted an empirical evaluation to investigate learners' flow, technology acceptance, learning performance, and the process of learning behaviors in the game. The results showed that through the game learners' learning performance were improved and they had high acceptance and flow.

Keywords: Game-based learning, virtual Reality, chemistry instruction, situated learning, Scaffolding, Flow

1. Introduction

In the chemistry courses of the organic compound learning units including abstract concept of compound structure and the chemical reaction through repeated experiment. Nonetheless, real-world practice can be expensive and dangerous, especially in the context of chemistry experiment (Lu, Hou & Wang, 2017). Computer-assisted learning could provide a simulated world for learners to freely and safely explore the learning context and repeatedly practice the procedures to learn. In recent years, the virtual reality has been widely used in chemistry learning. Virtual reality can promote students' chemical learning achievement (Barata, Ribeiro, & Nunes, 2015; Merchant, Goetz, Keeney-Kennicutt, Kwok, Cifuentes, & Davis, 2012). Meanwhile, game-based learning could be beneficial in promoting learners' motivation and engagement in learning.

Our research team (Mini Educational Game group, eLearning Research Center of National Taiwan University of Science and Technology – http://www.ntustmeg.net) developed a 3D educational game "*Through the Organic Adventure* ©" for organic compound knowledge instruction. The game is a first-person shooting game. This game integrates virtual reality, which combines the learning of organic compounds with the situation. The game integrates scaffolding learning. The clues of principals of organic compounds, which appear in the scenes of the game as scaffoldings while the game goes on, offer learners guides and clues that are associated with learning units. By exploring the clue scrolls, knocking down monsters and picking up items in the 3D maze, learners will be able to obtain chemical compound of chemical synthesis in the game (Figure 1). With the multiple scaffolding mechanism of several levels, learners can learn from the basic compounds gradually to more complicated compounds. Learners have to put correct compounds into different lattices of synthesis, calculating equilibrium factor then put in correct quantity of compounds. Players have to solve every chemical formula in each level, so that they can open the locked door and move on to the next room (i.e. level) (Figure 2). When encountering failed synthesis, learners will have corrective feedback as scaffolding given by the game. When it comes to successful synthesis, the game will give

complete knowledge of synthesis as scaffolding. When players' click the compounds in the inventory during synthesis, there is relevant information of compounds as scaffolding, which assists players' cognitive thinking. The study aims to develop the game and evaluate the learners' learning effectiveness, flow, and technology acceptance.

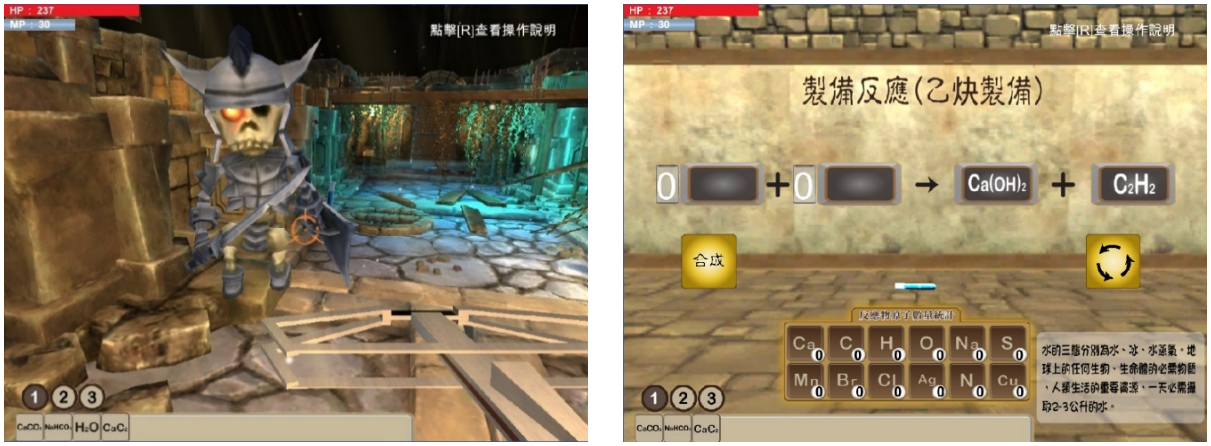

Figure 1. Left panel – Exploration and Fighting in the game context; Right panel – Problem-solving and scaffoldings

2. Method

Participants in this study were 49 senior high school students in northern Taiwan (25 males, 24 females, their average age was 16.68). In order to explore the learners' technology acceptance and flow, the study adapted the technology acceptance questionnaire by Davis (1989), in which the two dimensions perceived usefulness and perceived ease of use were emphasized. Participants' flow state was evaluated through Kiili's (2006) flow scale, which was translated and revised by Hou and Chou (2012). The scale includes two dimensions, namely the flow antecedent and flow experience. All scales were measured with five-point Likert scale. The reliability of the technology acceptance questionnaire (Cronbach's alpha=0.83) and the flow questionnaire (Cronbach's alpha=0.74) showed high internal consistency.

In the analysis of learning effectiveness, the contents of pretest and the posttest were the same. The test was designed referring to the composition of organic compounds, including 13 questions. The participants firstly had the pretest (10 minutes), and played the game (40 minutes), which was followed by the posttest (10 minutes) and the technology acceptance questionnaire and the flow questionnaire (10 minutes).

3. Results and Discussions

For learning performance, a paired-samples t-test was used to compare the results of learning effectiveness between the pretest and posttest. The results of the pair t-test showed no significant (but near significant) difference in learning effectiveness ($t=1.98$, $p=0.05$). The scores in the posttest ($M=17.12$, $SD=10.37$) were higher than that of the pretest ($M=19.29$, $SD=11.83$), and it suggested that this game may improve the learners' understanding of the organic chemistry in a certain degree.

As for technology acceptance, the overall scores and the scores for each dimension were above three, which suggested that the learners' perceived usefulness ($M=3.62$) and perceived ease of use ($M=3.63$) were high (see Table 1). As for the flow, the overall flow score ($M=3.77$), flow experience ($M=3.69$), and flow antecedent ($M=3.87$) were all above the median (higher than 3, the median of the five-point Likert scale) (see Table 2). Overall, learners have high level of flow and learners generally perceived the game as easy to play and useful for supporting their learning.

Table1: The mean and standard deviation of technology acceptance scores.

Dimensions	M	SD
TAM	3.63	0.64
Usefulness	3.62	0.79
Ease of use	3.63	0.75

Table 2: The mean and standard deviation of flow state scores.

Dimensions	M	SD
Flow	3.77	0.77
Flow antecedent	3.87	0.79
Flow experience	3.69	0.81

4. Conclusion

This study developed an educational game, "*Through the Organic Adventure* ©", which is integrated with virtual reality, situated learning, and multiple scaffolding for organic chemistry learning. The evaluation results of the game suggested the game may be helpful to support learners to understand of the organic chemistry. The learners could know more about the context have better performance and find the clues as scaffolding. The learners had high acceptance for this game and they thought the game met their learning needs, was easy to handle. Future research can record and analyze students' learning process to investigate their behavioral patterns using sequential analysis (e.g. Hou, 2015).

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