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Integrating Board Game Elements, Collaborative Discussion, and Mobile Technology to a Gamification Instructional Activity - A Case of High School Chemical Course

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Abstract

In recent years, gamification in learning has been a proliferative topic and is regarded as an effective way to promote students' learning motivation and engagement in learning. This study applied a Gamified model – CSLS teaching model, which integrated Card-game, Slides, and Learning Sheets for designing a collaborative learning activity to support organic chemical compounds learning. A collection of online materials, which could be accessed via mobile devices, were used as cognitive scaffoldings. The learning activity was employed in a high school of northern Taiwan with 72 participants. In addition, as a comparison to the CSLS model, a conventional lecture-based instruction was employed with 79 participants in the same school. Both groups were taught by the same teacher. Results of comparing the learning performance between the two groups indicated that the students in the gamified learning activity showed significantly greater improvement than students in lecture-based teaching model did. This study also introduced a formative approach to oversee and analyze students' learning progress in the collaborative learning process. Results indicated that students showed progressive improvement while the learning activity in progress. These findings suggested that CSLS teaching model could be an effective approach to promote learning.

Keywords: Chemistry instruction, Gamification, Collaborative learning, Card game

1 Introduction

Gamification has been a trending topic in recent year as it is considered an effective strategy to drive motivations [1][2]. Motivation plays an important role in learning process [3]. High motivation could promote students' engagement in the learning activity and thus contribute to better learning performance. For subjects that involved abstract and complex concepts, the high

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cognitive challenge might diminish students' motivation to learn. In the aforementioned situation, gamification seems to be an ideal strategy to drive learning motivation and promote better learning performance.

Gamification refers to "apply game elements in non-game context" [2][4]. In educational context, gamification is strategy that apply game elements to design learning activities for promoting learners' motivation, engagement as well as their performance. Speaking of game-based learning (GBL), serious games or educational games are commonly referenced teaching practice to serve educational purposes [5]. Serious games or educational games are inherently a game by itself only they incorporate learning elements, such as knowledge acquisition, skills development, cognitive interaction, to the gaming process. In contrast, gamification learning refers to learning activities that integrate game elements, such as point, story, leaderboard, etc., to the learning process. In this manner, serious games are generally designed for specific learning subjects. Therefore, it could be inflexible and costly to adapt one serious game to another context. That is, when the learning subjects changed, the serious game might need to be overhauled for the new learning subjects. Comparatively, gamification in learning is a set of game elements and mechanics for learning activities. The same game elements and mechanics might be applied to new learning subjects without extensive modification, which make gamification a more adaptive teaching strategy in game-based learning.

To exploit the effectiveness of the gamification in learning, this study applied CSLS teaching model that integrated Card game, Slides, and Learning Sheets as major components. In specific, card games are used for promoting interactive learning, learners' motivation as well as providing cognitive scaffolding. Meanwhile, slides are for introducing scenario context and preparing essential basic knowledge for learning. Lastly, learning sheets are for learning scaffolding and formative evaluation. CSLS teaching model was proposed by the Mini Educational Game research group from National Taiwan University of Science and Technology (MEG-NTUST) in 2017.

The gamified collaborative learning activity, which adapted the CSLS teaching model, was employed in two phases in this study. Firstly, the instructor using slides to present the background story, rules, and goals of the card game, which was to be used in the learning activity. In the second phase, students worked in pair for playing the card game. While playing the game, students were allowed to access the clues and related chemical knowledge by scanning QR code provided by the instructor. At the same time, each pair was provided with a learning sheet and was asked to complete it by the end of the game. The learning sheet here was used as a scaffold as well as a formative assessment. The details of the gamified learning activity are to be presented in the Method section.

To assess the effectiveness of a learning activity or instructional strategy, evaluating the learning outcomes was a common practice. However, simply evaluating the learning outcomes could potentially overlook the process, such as the cognitive interaction among learners, the process of knowledge construction, or how learners access the learning materials in the learning activity. In recent years, researchers have adopted research methods to explore the behavioral patterns for delineating the process perspective [6]. By exploring the process of collaborative learning activities, the researchers and instructors could thus able to adaptive formative assessment instead of simply using summative assessment. In addition, formative approach would be used to provide feedback and correctives to the teaching design [7]. The instructors could accordingly inspect the learning activity design for fostering specific behaviors or cognitive process [6]. Therefore, to address the aforementioned literature gap, in this study, we introduced a formative approach to depict the learning process of the gamified organic chemical compounds learning activity.

This study seeks to advance the knowledge of collaborative learning in two novel ways. First, this study applied the CSLS teaching model, which integrated board game elements for

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promoting learning motivation as well as providing cognitive scaffolding in the learning process. Second, this study employed a formative approach to analyze learners' learning progress in the collaboration activity. This formative assessment could serve as feedbacks for the instructor to check the learning progress of each pair. This study adapted the CSLS teaching model to design an organic chemistry gamified instructional activity. Then, an experiment was conducted to evaluate its effectiveness. Concluding from above, this study proposed two research questions as follows:

(1). How are students' perception and experience with the CSLS model-based learning activity.

(2). How students' learning performance are improved with CSLS model-based learning activity.

2 Method

2. 1 Introduction of the learning activity

This study designed a gamified collaborative learning activity based on the CSLS teaching model for organic chemistry learning. The learning activity was consisted of two challenges. Before the challenges began, the instructor introduced the story of the game. In the story, a world renown scientist and a junior scientist (the role that student played) were poisoned with two mysterious toxic chemical compounds by a mad scientist. The goal of the game was to find out the characteristics of the two toxic chemical compounds within a limited time in order to save the scientist. The first challenge was to identify five functional groups in the chemical structure of the first mysterious toxic chemical compounds (As shown in Figure 1, five functional groups were in red rectangle). Students were allowed to collaboratively discuss and find out the names of the five functional groups and uploaded the answers to a Google form via a QR code.

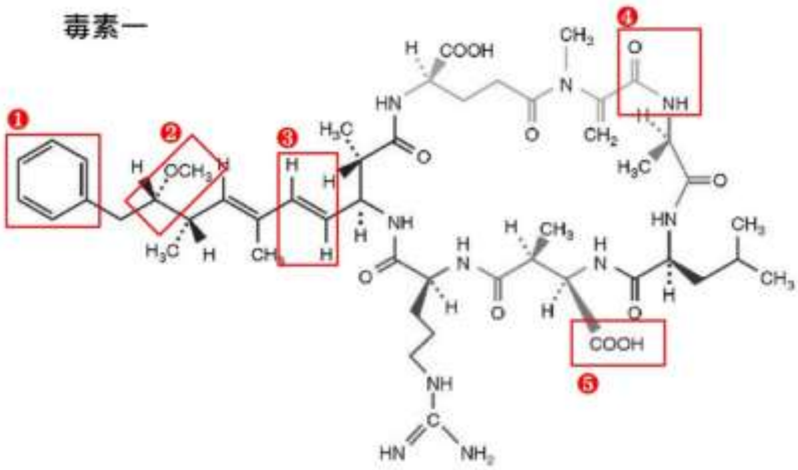

Figure 1: The instruction for the first challenge.

After completing the first challenge, the second challenge was to manipulate the molecule tokens to construct the chemical structure of the second toxic chemical compound according to the given clues. The clues provided important characteristics of the chemical compound. For instance, one of clues is "it smells like fruit and it could initiate a hydrolysis reaction with alkali." Figure 2 showed the molecule tokens used in the game. Varied bonus scores would be given according to the complexity levels of the organic chemical compounds. While playing the game,

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each group was also given a set of cards with text and QR-code printed on them. Students could scan the QR code to access the online materials, such as webpages, Wikipedia entries, textbook chapters, documents and videos, to help me solve the problems in the game (Figure 3). These online materials also served as cognitive scaffoldings for the students. In the second challenge, each group was also given a learning sheet. Each group had to draw the chemical structure of the toxic substance.

Figure 2: Composing molecule tokens for second challenge.

Figure 3: QR code cards for quick accessing online materials in Wikipedia, YouTube, online documents, or webpages.

2.2 Participants and Procedure

To evaluate the gamified learning activity as well as students' learning performance, this study conducted an experiment with 151 participants. The participants were 11th grade students from a high school in northern Taiwan. The learning subject, which was the organic chemical compounds, was new to the students. Students had no prior knowledge about the subject to learn.

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Students were assigned to experimental (n = 72, female = 46, male = 33) and control group (n=79, female = 34, male = 38). The experiment group participated in the gamification instructional activity, while the control group participated in the lecture-based instruction. Both groups were taught by the same teacher, who had more than eight years in teaching chemistry.

For the experimental group, the teaching procedure was (1) pretest (15 minutes); (2) employing the gamified instructional activity (16 minutes for each challenge, for a total of 32 minutes); (3) posttest (15 minutes); (4) completing a survey for game evaluation and gaming experience. In the gamified instructional activity, students worked in pair to tackle the two game challenges. In other words, there were 36 pairs of students played the game. For the control group, the gaming session was replaced with lecture session with other steps remained the same.

The pretest and posttest consisted of 15 questions to examine students' understanding of functional groups and structure of organic chemical compounds. The first eight questions asked students to identify the chemical structure of specified functional groups and fill in the functional group names accordingly. These eight questions were used to examine students' understanding of the chemical structures. The following seven questions asked students to draw the chemical structure of specified organic chemical compounds. For these seven questions, students not only have to identify the characteristics of the chemical compounds, they also need to draw the structure by hand, which could involve higher level of cognitive process. For the 15 questions, each correct answer was given one points, which resulted in a total of 15 points. The questions are listed in Appendix.

To evaluate students' perceptions toward the game and their experience with the game, this study administered Killi (2006)'s flow scale, which was translated to Mandarin and revised by Hou and Chou (2012) [8][9]. The flow scale consisted of two dimensions, the flow antecedents and flow experiences. All items were measured using five-point Likert scale. The reliability of the flow scale showed high internal consistency (Cronbach $\alpha = 0.92$).

In the second challenge, each pair was asked to manipulate the molecule tokens to compose the chemical structure of the toxic substance. This study introduced a formative approach to examine students' learning progress. Students were asked to take pictures of the structure they were composing every 2 minutes and upload the pictures to a Google drive. The teacher would immediately examine each pair's uploaded pictures to check their learning progress. This formative approach allowed the teacher to provide timely feedback according to each pair's learning progress.

3 Results

In the first challenge of the game, students had to answer the names of the five chemical structures via a Google form (see figure 1). Each correct answer would be given one points. The average score is 3.58 (SD = 0.84). This finding suggested that most students were able to work out the correct answer within the time limit.

For the second challenge in the game, this study proposed a formative approach for assessing students' learning performance in the game play. To illustrate how to analyze the results of the formative approach, the present preliminary study randomly sampled 9 pairs (25%) of the participants in the gamified instructional activity and analyzed their learning process using the formative assessment approach.

Table 1 showed the results of formative assessment analysis. In the second challenge of the gamified learning activity, each pair was asked to take picture of their work and upload it to a Google form. When a pair uploaded a picture that contained one correct chemical structure, the

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pair would be given one score. There were three correct chemical structures in total.

In general, students were able to compose correct chemical structure as the game in progress. In specific, as the time went by, we could observe that students exhibited a steady upward learning performance in terms of the average scores. This finding suggested that the CSLS teaching model-based instructional activity could promote students' collaboration in problem-solving task.

Furthermore, through this formative assessment analysis, we could observe different patterns among pairs. For example, pair 6 was the only pair that composed all three correct chemical structures. In Table 1, we could see that pair 6 gradually figured out the correct structure. In contrast, pair 5 and pair 7, we found they would come up with a correct structure and then went back to the incorrect one. For example, pair 5 showed a back and forth pattern in the fifth minute to ninth minute. Also, in the last minute of the gaming session, pair 5 broke down one of the two correct chemical structures. This pattern implied that pair 5 might not be quite sure about their answers and might employ trail-and-error strategy to tackle the challenge. With the formative assessment approach, the instructor could diagnose students' learning process and provide timely and necessary scaffoldings to help students.

At the same time, Table 1 showed that pair 2 and pair 8 were lag pairs. During the game session, pair 2 didn't come up with any correct structures while pair 8 composed only one correct answer. Through this formative approach, the instructor would thus be able to oversee each pair's learning progress. When spotting that students fall behind, the instructor could provide prompt intervention in a timely manner. Nonetheless, as this study is still in the preliminary stage, in order to explore each pair's behavioral patterns in detail, more elaborated analysis is required.

Table 1: The correct answers in every other two minutes

Score	minutes							
	1	3	5	7	9	11	13	15
Group 1	0	0	0	1	1	1	1	1
Group 2	0	0	0	0	0	0	0	0
Group 3	0	0	0	0	1	1	1	2
Group 4	0	0	0	0	0	1	1	2
Group 5	0	1	2	1	2	2	2	1
Group 6	0	0	1	1	1	2	3	3
Group 7	1	1	1	2	1	1	2	2
Group 8	0	0	0	0	0	0	1	1
Group 9	0	0	0	0	1	1	2	2
Average	0.11	0.22	0.44	0.56	0.78	1.00	1.44	1.56

Students' evaluation of the game (in terms of flow antecedents) and experience with the game (in terms of flow experience) were summarized in Table 2. Students' generally evaluated the game positively (mean = 3.56) and had positive experiences with the game at the same time (mean = 3.25). In addition, as males were generally regarded as typical gamer, this study further conducted an independent t-test to explore the possible gender effect. The t-test indicated that there were no significant differences between male and female students in both game evaluation and gaming experience (t-statistics for flow antecedents = 0.36; for flow experience = 0.43). This finding suggested that the proposed gamified learning activity wasn't preferred by a particular gender.

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Table 2: Results of t-test for the pretest and posttest.

Items	**Pre-test**		**Post-test**		
	Mean	**S.D.**	**Mean**	**S.D.**	***t-value***
CSCL teaching model	0.63	1.16	2.86	2.24	- 9.44***
Lecture-based teaching model	0.43	0.75	1.27	1.77	- 3.97***

***: p-value < 0.01

Lastly, as for the learning outcomes, Table 3 summarized the results of paired t-test for pretest and posttest. In average, the CSLS teaching model group and the lecture-based teaching model group both showed significant improvement. Regarding the prior knowledge of both experimental and control group, this study conducted a t-test for pretest score. Results indicated that the pretest score of the two groups showed no significant difference ($t = 1.216$, $p = 0.226$). In other words, before the learning activity, there was no significant difference between students' prior knowledge in both groups. This study further conducted an ANCOVA to compare the learning outcomes of the two groups with pretest scores controlled. The results suggested that the CSLS teaching model exhibited significantly greater improvement that the lecture-based group did (adjusted mean = 1.33, $F = 21.97$, $p < 0.001$).

Table 3: The mean and standard deviation of Flow and subdimensions of Flow

Dimension	**Mean**	**S.D.**	**Cronbach's alpha**
Flow	3.40	0.62	0.92
Flow Antecedents	3.56	0.73	0.90
Flow Experiences	3.25	0.62	0.83

4 Discussions and Conclusion

This study adapted the CSLS teaching model to design a gamification instructional activity. The CSLS-based instructional activity integrates board game elements and cognitive scaffolds, accessed using mobile devices, for designing a gamified collaborative learning activity. In specific, the CSLS teaching model uses card-game to promote learners' motivation to participating in the learning activity. Meanwhile, the slides and learning sheet are used to provide the cognitive scaffolding in the learning process. The subject to learn was organic chemical compounds. Also, we introduced a formative approach to assess learning progress. The proposed formative approach enabled the teacher to promptly intervene in the learning process. As for the evaluations of the gamified learning activity, results indicated that students generally evaluated the learning activity positively, had positive experience with the game. Furthermore, their learning performance was significantly improved in comparison with lecture-based teaching model.

The gamification instructional activity doesn't not overly rely on technology. Instead, the CSLS teaching model seeks to adapt affordable technology with board game elements to design gamified collaborative learning activities. Employing technology to support learning has its advantages; nonetheless, there could be limitations as well. First, technology itself can be a

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distraction which makes students overly focus on technology rather than learning [10][11]. Second, technology can be costly. For instances, a mobile learning activity might require each student to have one mobile device. Or, a Virtual reality-based learning activity might cost much on VR equipment. These technology resources and environment might not be available in most educational context due to limited budget. In this study, each pair of students could share a mobile device to scan QR code for accessing online materials in various formats. Then, they had to work collaboratively to manipulate the molecule tokens to find the answers. The "card game" in the CSLS teaching model facilitate a real-world collaboration instead of a virtual collaboration. In the CSLS teaching model, the role of technology is to "augment information" for learning, rather than being the center of learning. For instance, in this study, the teacher used QR code for accessing online resources, which provided students with abundant learning subject related knowledge. The teacher could easily incorporate other resources by simply replacing the QR code and online resources links. This approach maintained the adaptability of technology with relatively little concerns for distraction or cost.

While previous research generally focused on the effectiveness and learning outcomes of collaborative learning, this study introduced a formative approach to assess students' learning progress. In the gamified collaborative learning activity of this study, each pair had to take pictures their work (i.e. chemical structure) and upload them to a cloud drive while composing the chemical structure. The teacher could check the pictures to assess how each pair performed as the learning activity in progress. This approach allowed the teacher to provide prompt intervention for improving students' learning performance. In addition, the results of formative assessment could be a feedback for the design and implementation of the learning activity [7]. For example, the teacher could provide cognitive scaffoldings when students encounter a bottleneck or fall behind in the learning activity.

In conclusion, the CSLS teaching model is an adaptive and easy-to-implement model. We seek to utilize the adaptability of information technology and try to minimize the potential concerns of it. With careful design, collaborative learning activity using CSLS teaching model could be employed to a wide variety of learning subjects to promote students' learning engagement as well as their learning performance [12][13][14].

4.1 Research limitation and future research

Without exception, there are limitations for this preliminary study. First of all, this study employed a CSLS teaching model-based instructional activity to support learning organic chemical compounds. The evaluations of the gamified learning activity as well as students' learning outcome were all positive. Nonetheless, the effectiveness of employing CSLS teaching model to other learning subjects is still required further exploration in order to refine the CSLS teaching model. Second, this study introduced a formative approach to assess students' learning progress, However, this preliminary study did not analyze the interaction patterns of each pair of students while playing the game as we did not collect their interaction in the game time. Future research is encouraged to record the game session using video recorder for detailed analysis or to employ information technology to assist teachers in assessing students' learning progress, such as pattern detection, auto-grading, etc. Lastly, this study didn't explore the behavioral patterns of students' interaction or their discussions in the learning activity. By exploring students' behavioral patterns and discussion content structures could delineate a clearer picture of students' collaboration. Previous studies have employed quantitative content analysis (QCA) and leg sequential analysis (LSA) to look into the collaborative learning process for exploring learners' behaviors of knowledge construction, cognitive processes, and social interaction [6][15]. Future research is

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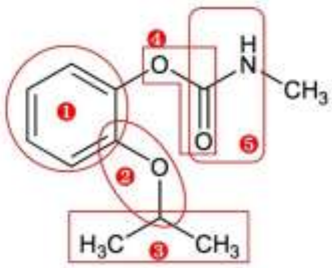
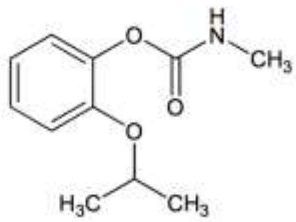
encouraged to employ multi-method approach to depict the learning process, which would greatly improve our understanding of how and why a teaching model can be beneficial to the learning.

Appendix: The 15 questions for pretest and posttest

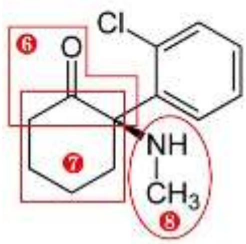
Please identify the ❶ - ❽ functional groups in the following molecule and write their names. – One point for each correct answer.



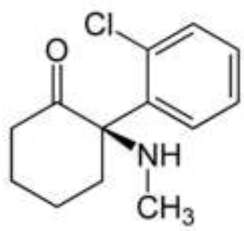
(1) Insecticide (❶ - ❺)



Original Image



(2) Ketamine (❻ - ❽)



Original Image

Please draw the structural formula of the molecular structure of the following organic categories. (draw basic structures) – One point for each correct answer.

(1). Alcohol (2). Aldehyde (3), Acid (4). Alkyl halide (5). Acyl halide (6). phenol (7). Alkyene

Reminder: The category is not a functional group, the name is not the same.

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