

## “Spot the differences” Game: An Interactive Method That Engage Students in Organic Chemistry Learning

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**ABSTRACT.** For the first time, the spot the differences (STD) game was employed in the teaching of basic organic chemistry course. Three sets of paired pictures associated with selected topics in organic chemistry were presented to the students and they were required to spot the differences between the two pictures. Based on the students' pre and post self-assessment, the STD game resulted in several positive learning outcomes as indicated in the students' reflective writing, including knowledge recall, deeper understanding of a subject, enhanced analytical skill, motivation and fun-filled learning, learning from peers and self-empowerment in learning. The STD game is a desirable teaching and learning tool, as learning in an entertaining and interactive way is highly sought after in today's classroom, especially to novice students. In the future, the STD game can be modified and implemented to cater the needs of different courses and topics.

**Key words:** Spot the differences, Basic organic chemistry, Interest and learning

### INTRODUCTION

Organic chemistry is regarded to be one of the difficult subjects among novice learners. In particular, students perceived that certain topics in organic chemistry such as nomenclature, molecular visualization and reaction mechanism were tedious, complex and hard to rationalize.<sup>1</sup> Previous journals have reported that students have developed anxiety and negativity towards chemistry subjects.<sup>2-4</sup> To that end, many efforts have been explored on interactive learning methods, including incorporating games in the teaching of organic chemistry course and the results were shown to be positive by students' feedback.<sup>5-8</sup> For many years, new teaching strategies and classroom activities are highly sought after by educators to facilitate students' learning, as well as to enhance students' engagement and performance in the subject taught.<sup>9</sup>

Educational games are recognized as one of the effective means to aid teaching and students' engagement and discussion in the classroom.<sup>10</sup> It can be easily modified and adapted to cater for any age group and levels of learning. In addition, it allowed the social aspect of learning to be addressed by exchanging opinion among students and enabled active learning environment in the classroom.<sup>11</sup> In the past, a variety of educational games format has been described to instill interactive learning, such as the card game,<sup>12-15</sup> table-ten-

nis game,<sup>16</sup> guessing game,<sup>17-19</sup> Jeopardy<sup>20</sup>, Who Wants to be A Millionaire<sup>21</sup> and so forth. Unfortunately, most of these games are consumer games, which is not cost effective or take more than an hour to implement. According to Prensky (2008), an educational game should be cost-effective, simple, less time-consuming and can be easily adapted from other games.<sup>22</sup>

The approach employed in this study involved the implementation of spot the differences (STD) game. It is a simple, cost-effective and popular game which requires the participants to compare a pair of images and identify the differences between the two very similar images. Apart of this, this game offers educators who seek for an alternative pedagogy in classroom teaching and to instill the love of learning through education game. According to a survey, students' concentration decline after 10–30 minutes of learning.<sup>23</sup> In this game, noticing the differences requires visual attention and visual awareness. In particular, this activity promotes cognitive and collaborative learning, of which are considered as components of active learning. Previously, the STD has often been employed as a cognitive test for detecting the onset or progression of dementia.<sup>24,25</sup> Besides, the STD activity was also shown to be an effective tool to create active learning environment in language learning.<sup>26</sup> So far there is no similar study reporting on the use of this type of game for the teaching and learning of chemistry or science courses.

In this study, we have evaluated the efficiency of the game by pre and post self-assessment to gauge students' learning after the implementation of this activity.

## METHODOLOGY

### Subjects

The STD game was introduced to students who enrolled into the environmental analytical chemistry program, at the Universiti Malaysia Terengganu. The intervention group which received the STD activity consists of 58 students and all of them were in their second semester of 2017/18 session.

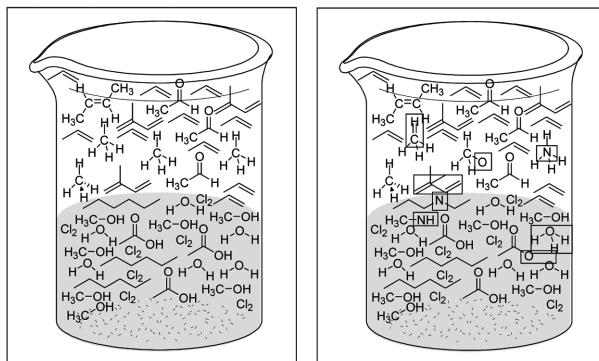
### STD Activity

The STD activity was implemented in the basic organic chemistry course, which was comprised of two one-hour lessons in a week for a total of 14 weeks. The game was presented to the students for three times, at week 2 (Activity 1), week 4 (Activity 2) and at week 6 (Activity 3) at the interval of the lecture. In this game, students were required to identify the differences between two very similar images as depicted in the Activity 1, 2 and 3 (Fig. 1). Students were allowed to discuss with their peers and ten minutes were given to solve the each activity.

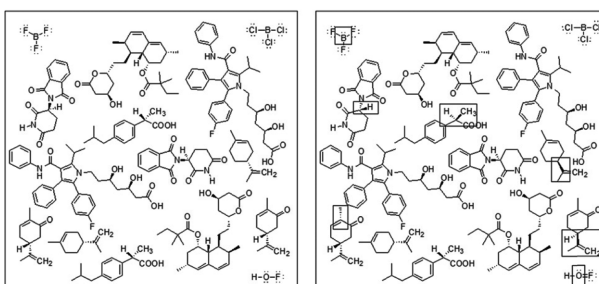
At the end of each activity, the course instructor discussed the answers with the students. Apart from providing fun and challenging environment for learning, this game was developed in an effort to teach students on selected topics of the basic organic chemistry course. For example in activity 1, students were required to explain the disparity of the highlighted structure (Activities 1-3) from the perspective of organic chemistry. From here, the instructor and students could recall and reinforce knowledge in the following topics - formal charge, covalent bonding and octet rules, which were taught during the first lesson in the basic organic chemistry course. Next, activity 2 was introduced to emphasize on Lewis structures and stereochemistry.

Prior to this activity, students were taught on the subjects of Lewis structures and stereoisomers. In the topic of stereochemistry, a slight change in stereochemistry could affect the pharmacological and olfactory properties of a molecule. For example, *S*-thalidomide is known to possess sedative effect but the *R*-thalidomide is a teratogenic compound. Another example is *R*-limonene which contributes to the orange fragrance, whereas *S*-limonene has lemon scent. Activity 3 was designed to enable students to learn about the topic on arrow pushing, which is a crucial lesson covered during the first year of basic organic chemistry course.

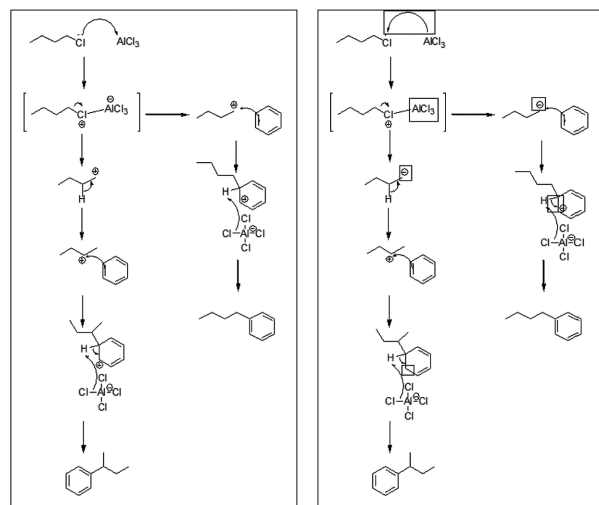
### Activity 1



### Activity 2



### Activity 3



**Figure 1.** Pairs of pictures directed to students in the STD game. Answers were indicated in the boxes.

In this activity, students need to identify some of the common mistakes, such as not to break single bonds, arrow tail should start from where the source of electrons is located with the arrow head points towards the electron acceptor to indicate the electrons movement. Essentially, this activity has provided a platform for students to engage, enjoy and created a better tool for the teaching and learning of organic chemistry in place of the conventional teaching process.

1. What is the formal charge on the nitrogen atom of ammonia?
2. What is the formal charge on the nitrogen atom of ammonium?
3. Draw the Lewis structure of H<sub>2</sub>O.
4. Draw the Lewis structure of BF<sub>3</sub>.
5. Enantiomers are molecules with different pharmacological properties?
6. Enantiomers are molecules with the same physical and chemical properties?
7. Draw reaction mechanism with curved arrow to indicate the bond making and breaking of bonds in *tert*-butyl bromide.
8. Draw reaction mechanism with curved arrow to indicate the bond making and breaking of bonds in acetone.
9. Draw reaction mechanism with curved arrow to indicate the bond making and breaking of bonds in hydrogen cyanide.

**Figure 2.** Questions asked on pre- and post- self-learning assessment of the STD game.

### Instrument

In this activity, a total of 58 students have participated in the pre and post self-learning assessment (*Fig. 2*). Students' responses to their self-learning assessment were analyzed by two of the authors. In this regard, a consensus was reached on the overall analysis with an inter-rater reliability of 96%. The data analysis was performed using the Statistical Packages for Social Sciences (SPSS) software. In addition, participants were administered with a post-game survey after the activity to assess the effectiveness of the game.

Participants were asked to fill up an anonymous five-point Likert scale post-game survey to understand their perception on the purpose of STD game (*Fig. 3*). Anonymity in post-game survey would reduce the social desirability bias and led to a more reliable survey. Participants were also invited to submit a reflective writing to reveal about their learning experience. In this way, the data obtained from this study would enable the researchers to further improve on the current activity, so that it can motivate students' interest and advance their knowledge in the particular subject.

1. The STD is entertaining and fun.
2. The instruction of play is easy to understand
3. Occasionally, I would prefer educational game for learning.
4. The STD motivated me to learn more about organic chemistry.

**Figure 3.** Questions on the perception on the purpose of STD game.

## RESULTS AND DISCUSSION

### Pre- and Post-Assessment on Students' Self-learning

A pre and post self-assessment test, which comprised of nine questions, was directed to students before and after playing the STD game. Students were asked to answer the questions that were stipulated to examine their understanding on the selected topic in the basic organic chemistry course before and after playing the STD game by filling up the worksheet shown in *Fig. 4*. The worksheet was designed to review on the concepts and theories learnt in the basic organic chemistry course, which include topics such as formal charge, covalent bonding and octet rules, stereochemistry and arrow pushing. Based on the qualitative and quantitative analysis, students marked a significant increase in the understanding of these concepts and theories as reflected in their post-worksheet as compared to pre-worksheet. An example of the student worksheet who marked an increased in the understanding of these topics before and after playing the STD game was shown in *Fig. 4*. This student did not attempt questions 5 to 9, due to lack of understanding on these organic chemistry topics and thus reluctance to tackle the rest of the questions. After the implementation of the STD game, this student attempted all the questions and has recorded six out of nine correct answers. A careful examination on this student's reflective writing revealed that one has to be equipped with concept understanding before solving problems. The student's comment was as follows:

*Basic organic chemistry makes me feel so excited when I understand the concept and the characteristic of a compound. But, when I could not understand, it makes me feel annoyed. [student 4]*


The paired *t* test was employed to analyze the performance of the intervention group (*Table 1*). The result of paired *t* test showed that there was a statistical difference in the understanding of introductory chapter of organic chemistry (formal charge, covalent bonding and octet rules, stereochemistry and arrow pushing) after activity 1 of the STD game ( $t=28.540$ ,  $df=115$ ,  $p=0.000$ ). A closer examination on the students' average scores (percentage) before and after playing the STD game, showed that the administered activity had improved students' understanding on the topics learnt (*Fig. 5*), thus students scored statistically better after the implementation STD game. However, there were some limitations that were identified in this study. The teachers' effect and control group that was unable to be measured in this study due to there was only one basic organic chemistry class per semester.


**a**

1. What is the formal charge on the nitrogen atom of ammonia?
2. What is the formal charge on the nitrogen atom of ammonium?
3. Draw the Lewis structure of H<sub>2</sub>O.
4. Draw the Lewis structure of BF<sub>3</sub>.
5. Enantiomers are molecules with different pharmacological properties?
6. Enantiomers are molecules with the same physical properties?
7. Draw in the mechanism arrow to indicate the bond making and breaking of bonds in *tert*-butyl bromide.
8. Draw in the mechanism arrow to indicate the bond making and breaking of bonds in acetone.
9. Draw in the mechanism arrow to indicate the bond making and breaking of bonds in hydrogen cyanide.

1. Formal charge =  $\frac{\text{valence e}}{\text{e}} - \frac{\text{non-bonding e}}{\text{e}} - \frac{\text{bonding e}}{2}$  (H - N - H)  
 $N = 5 - 2 - \left(\frac{6}{2}\right) = 0$  ✓





2.  $5 - 0 - \left(\frac{8}{2}\right) = +1$  ✓

3.  ✓

4.  ✓

5. ??

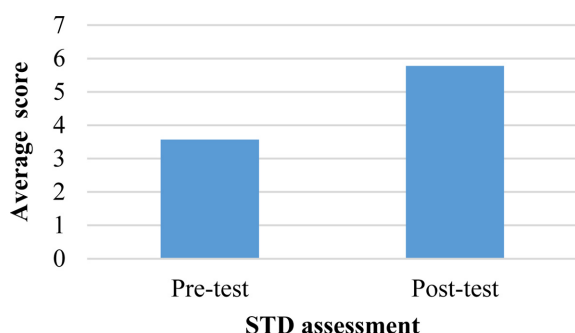
**b**

- 1) The formal charge on the nitrogen atom of ammonia  

- 2) The formal charge on the nitrogen atom of ammonium  

- 3) Lewis structure of H<sub>2</sub>O  

- 4) Lewis structure of BF<sub>3</sub>  

- 5) Enantiomers are molecules with different pharmacological properties?  
 Yes
- 6) Enantiomers are molecules with the same physical properties?  
 Yes except that they rotate plane polarised light in opposite directions.

**Figure 4.** Worksheet of a student who marked an increase in the understanding of concepts and theories of selected topics in the basic organic chemistry course (a) before and (b) after playing the STD game.

**Table 1.** Means and standard deviations of pre-test and post-test, and result of paired t-test between pre- and post-assessment

Pre-test		Post-test		t	df	p
Mean	SD	Mean	SD			
3.569	0.701	5.776	1.077	28.540	115	0.000



**Figure 5.** Comparison of the average score made by students in the pre- and post- self-learning assessment after playing the STD game.

### Post-Game Data

Students were given the post-game survey to further understand their learning experience after playing the STD

game. In *Table 2*, the post-game survey revealed that as a whole the students enjoyed the STD game. This was evident that about 97% students ( $M = 4.62$ ) feedback that the STD was entertaining and fun. In addition, students also responded that the instruction to play in the STD game is easy to understand ( $M = 4.83$ ) and they would prefer educational game in their learning ( $M = 4.88$ ). Last but not least, it was promising to note that about 95% students ( $M = 4.60$ ) feedback that the STD motivate them to learn.

### Students' Reflection on the Benefits of STD Game

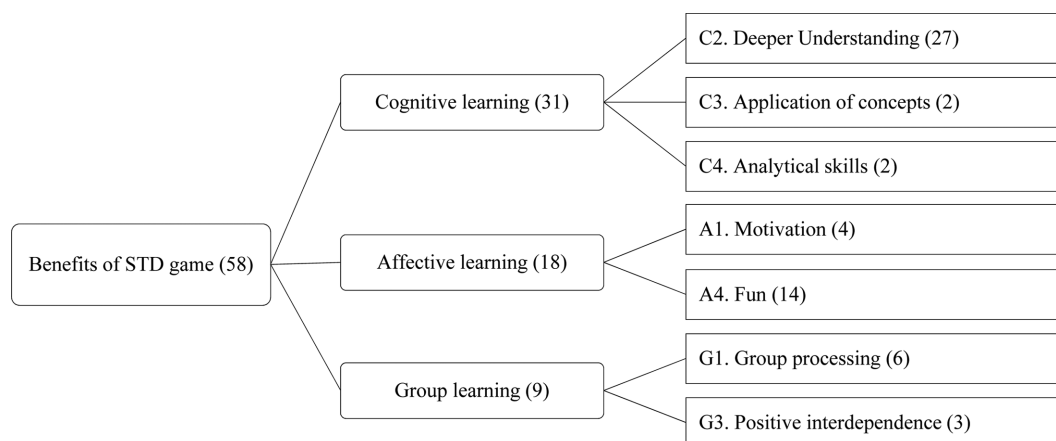
In order to learn about the benefits of this game, students' reflective feedback on the STD game in the basic organic chemistry course was analyzed and a systemic network was formed based on the Bloom's taxonomy (*Fig. 6*).

In the cognitive learning domain, 27 students feedback that the STD game have benefited them in the deeper understanding of concepts associated with octet rule, Lewis acids and bases and arrow-pushing. As indicated in the systematic network, the STD game has stimulated students' deeper understanding of a concept, which corresponds to the purpose of this activity and this finding was in agreement with

**Table 2.** Students’ perception on the STD game (N=58)

Question	Frequency					Mean (SD)
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	
The STD is entertaining and fun.	38	18	2	0	0	4.62(0.50)
The instruction of play is easy to understand.	48	10	0	0	0	4.83(0.38)
Occasionally, I would prefer educational game for learning.	51	7	0	0	0	4.88(0.33)
The STD motivated me to learn more about organic chemistry.	38	17	3	0	0	4.60(0.59)

5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree and 1 = strongly disagree



**Figure 6.** Systematic network built based on students’s reflective writing (N = 58).

our previous study.<sup>6</sup> Selected exemplars of students’ feedback on the STD game were shown as follows:

*First is the arrow. Arrows are used to indicate the movement of electrons. Second, arrows are never used to indicate the movement of atoms directly. The arrows indicate atom movement indirectly as a result of electron movement, in which a covalent bond is made and broken. [student 24]*

*From the basic organic chemistry that I learnt, carbon atom can only have 8 electron valence and is tetravalent. In this activity, I observed a carbon atom that form five bonding, which has violated the concept that I have learnt. [student 9]*

*AlCl<sub>3</sub> is the Lewis acid. Lone pair of chlorine in chloropentane attacks the AlCl<sub>3</sub> and a tetrachloroaluminate, an electrophile is formed. [student 18]*

*It helps us to build a strong foundation in the drawing of molecular structures, understanding and identifying the name of structures or isomers and finally understanding the concept of hybridization. [student 7]*

It was noteworthy that two students responded that this activity enabled them to relate daily life with the concepts learnt in the basic organic chemistry as indicated by their quotes below:

*Organic molecules make up a good majority of the matter that we see around us, especially life. They have these fascinating complex structures and it is really fun to figure out how their structures affect their functions. [student 1]*

*Chapters like stereochemistry and acids and bases taught me the importance of organic chemistry in daily life. [student 3]*

In addition, two students have commented that this activity enables the development of analytical skills, which is a crucial element in this course. Undoubtedly, students need to be equipped with analytical skill, able to recall knowledge and solve problems as required in both this activity and in this course. The excerpts from students’ reflective writing were shown as follows:

*I have realized that we need to pay more attention when do mechanism especially about the arrow, the charge and so on. [student 9]*

*We tend to make easy mistakes when we are not careful and this activity taught me, even though, the errors are not resulted from me, but identify it bring a lot of mean to me. [student 30]*

On the other hand, students have also benefited in the affective domain, in which four students have responded that this activity has motivated them to learn. On the other hand, 14 students reported to experienced joy in the study of the basic organic chemistry course along with the STD game. Selected extracts from students' reflective writing were shown as follows:

*This activity makes me feel nervous but fun. [student 16]  
I feel that this activity is complicated but I really enjoy it. [student 15]*

*This activity makes me feel excited and at the same time I'm able to gain new knowledge. [student 23]*

*This activity has aided me to be more concentrated in my study by identifying errors. Besides, it is a very interesting activity that motivate us to learn. I love to study in this way. [student 27]*

*Finally, in the group learning domain, six students have responded that this activity has benefited them by learning from peers as indicated in their reflective writing. Besides, this activity has enabled students to realize the importance of self-learning as recorded in three reflective writing.*

*Through this activity, I'm able to learn from active students, in which they're willing to share their knowledge that they learnt to help me. [Student 48]*

*The basic organic chemistry course makes me feel stress because I can't seem to catch up with the syllabus and I'm a slow learner. The activity is interesting but it takes a lot of time for me to figure out the correct answers. I have to work harder to excel in basic organic chemistry course. [student 33]*

On the contrary, there was a negative comment on the implemented STD game [student 52]. However, from the perspective of learning, if we view the comment positively, this activity might serve as an exercise to activate students' brain in learning, which was supported by a previous literature.<sup>27</sup> The excerpt of this student is as follows:

*Exhausted, as I need to think and observe carefully of the organic compounds. [student 52]*

## CONCLUSION

The goal of this activity is to offer an alternative and meaningful teaching and learning activity in the basic organic chemistry classroom. Furthermore, it is hopeful that by implementing the STD game, it would aid students to develop interest in this subject, which is an important element in the learning of organic chemistry. In this activity, the STD game has resulted in an increased understanding of introductory chapters of organic chemistry, such as formal charge, covalent bonding and octet rules, stereochemistry and arrow pushing, among participants ( $t = 28.540$ ,  $df = 115$ ,  $p = 0.000$ ). In addition, students also experienced several positive learning outcomes, including knowledge recall, deeper understanding of a subject, enhanced analytical skill, motivation and fun-filled learning, learning from peers and self-empowerment in learning. This activity can serve as a learning tool to boost up students' mental activation and as well as to retain their attention during lesson.

Owing to the advantages in the implementation of the STD games, such as cost-effective, simple instruction of play and not time-consuming, the STD game is a desirable game to novice chemistry students, especially when a more entertaining and interactive way of learning is highly sought after in today's classroom. In the future, the STD game can be modified to cater to the needs of different courses and topics.

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