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A Case Study on Using Uncritical Inference Test to Promote Malaysian College Students' Deeper Thinking in Organic Chemistry

Su-Yin Kan[†], Jeongho Cha[‡], and Poh Wai Chia[§,*]
[†]*Faculty of Health Sciences, Universiti Sultan Zainal Abidin, Terengganu, Malaysia*
[‡]*Division of Science Education, Daegu University, Gyeongsan 712-714, Korea*
[§]*School of Marin Science and Environment, Universiti Malaysia Terengganu, Terengganu, Malaysia.*
[*]*E-mail: pohwai@umt.edu.my*
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ABSTRACT. In Malaysia, the students' poor performance in mathematics and sciences needs immediate attention and remedies. In order to tackle this problem, an active learning environment that encourages students' question-asking capability must be molded. Transformation from traditional teacher-based approach to active-learning classroom is the key to develop question-asking capability. The classroom activity that the authors used in this study is based on the uncritical inference test to promote students' deeper thinking which encouraged students to verify facts that was previously learnt in classroom through group discussion activity. Three sets of uncritical inference test were developed and applied to Malaysian college course of basic organic chemistry. Students' answers to the impact of using uncritical inference test with a group discussion on learning and communication skills were positive.

Key words: Small group activity, Discussion, Organic chemistry, Classroom activity, Uncritical inference test

INTRODUCTION

According to the Trends in International Mathematics and Science Study (TIMSS), Malaysian students performed below average in the subjects of mathematics and science in comparison to its high income counter-part in the Southeast Asia region, such as Singapore, South Korea and other countries. The report cited that Malaysian students lacked of the three cognitive skills-knowledge recall, the application of knowledge in problem solving and the ability to reason in working through problems.[1,2] This is indeed worrying as the lack of quality graduates hinders the creation of highly skilled and innovative workforce, to drive Malaysia towards to the vision as a high income economy country by the year 2020.[3]

Teachers play an important role in the students' learning process. In Malaysia, formal education are mostly conducted in traditional teacher-centered method, where teachers emphasize on examinations, memorization and homework assignments to consolidate the understanding of student learning in the classroom. However this have left little room for engaging students in real-life learning experience and also diminished the fun of learning.[4] The practice of teacher-based instruction learning has made students passive in the participation of the learning process and contributed little to the education process, thereby hampering the purpose of education to produce all-rounded students in the long run.[5] On the contrary, a supportive classroom environment is very important to nurture the students in the subjects taught. Students displayed interest in learning based on the positive impression from syllabus and the classroom that can motivate them to excel.[6] According to Pines and West, science begin with what student thought is real.[7] Teachers only served as facilitators to promote students expression of ideas and challenge them with alternative ideas.[8] Thus, a new curriculum or activities must be implemented into the current syllabus so that we can bring back the joy of learning in classroom and at the same time to instill students' interest in science.

Organic chemistry is classically known as a very challenging subject, where student sometimes fail to grasp the fundamental concepts learnt during lecture. As a result, students lag behind the lecture easily and thus shun away from this subject.[9-11] In addition, a traditional undergraduate lecture which usually lasts 50 minutes could be a boredom and research had shown that this type of learning approach was not effective in maintaining student's attention.[12] The premise to this is a student's concentration decline gradually after 10–15 minutes.[13] To that end, many interesting activities have been introduced, including the Think-Pair-Share,[14] Concep Tests,[15] The Pause Procedure,[16] Questioning Purposefully[17] and so on to construct an active learning classroom environment. A common element of these approaches would be the transformation from the teacher-based instruction to student-based active learning in the form of group study, which can provide opportunity for students to present their own ideas, discuss freely within their group and reformulate their ideas after group study. These are prerequisite to developing higher level of thinking and problem-solving skills.[18] In order to maximize the impact of this kind of activity and deepen students' thinking in organic chemistry, teaching method that aimed to train students to verify fact, make inferences and examine them is of particular importance.

In this context, uncritical inference test[19] which is one of the efficient methods for encouraging question-asking and invoking deeper scientific investigation amongst the students was introduced to basic organic chemistry class. As an organic chemistry lecturer at the Universiti Malaysia Terengganu, one of the authors conducted an activity incorporates small group and problem solving skills. It is expected to make a positive impact to the learning process where students were keener to participate by voicing their own opinion compared to plain lecturing and or self-learning, and more importantly re-instilling their interest and curiosity in the subject.

METHOD

Subjects

This study was directed towards first year organic chemistry undergraduate students undertaking the *basic organic chemistry* subject with two one-hour lectures per week in a total of 14 weeks. All 90 students in the class were divided into 7 groups with 12-13 students per group in this activity.

Procedure

Before introducing the uncritical inference test, the "odd-one-out" activity[20] reported by Mant *et al.* was employed in basic organic chemistry class to evoke deeper thinking and creativity among students. With practice, students were trained to back-up their opinion with evidence, a higher level of cognitive thinking skill. The "odd-one-out" activity was carried out at the first week of the basic organic chemistry lecture to train student to "think-aloud". The usual practice of conducting classroom activities is reserved to 15 minutes before the end of the lecture.

In the following weeks, students were presented with a short story and a set of statements based on the story to undertake the uncritical inference test. They were then asked to decide based on the information given in the story, whether these statements were true, false or not sure. True statement is a statement that is defined as true based on the story and facts, while false statement is a statement that is defined as false about the information given in the story and not supported by facts. If the statement could be either true or false to a certain degree, then students should record "not sure" as their answer. Along the given story, students needed to make judgments and answer all the questions that were stipulated by the three case studies. Students were free to share their own views within the group and each group then nominated a leader to present their answer on behalf of the group.

After solving three sets of uncritical inference test, students' feedbacks on these activities were surveyed with questions about the components of this activity including cooperative learning, problem solving, and communication skill. In each item, students were asked to rate their impression about the activities with four options: poor, moderate, good, and excellent. Personal preference for the activity was also asked. Finally a total of 88 students answered to the questionnaire.

Class Activity with Uncritical Inference Test

Uncritical inference test was developed by Haney, and has been used in some study areas like semantics,[21] management education,[22] psychology,[23] special education,[24] and science education[25] to stimulate or evaluate students' reflective thinking skills. In this paper, our approach to instill deeper learning in organic chemistry employs the strategy of uncritical inference test to inform student about the significance of verifying fact, making inferences and examining them through group discussion, which is one of the strategy to train student to think deeper in science education learning. Although the test appeared simple, but its effectiveness is evident as it is employed by universities, colleges, corporate and government departments to enhance facts-checking and to build up effective communication.[19] Moreover, this test is easily adaptable to our objectives by incorporating elements of organic chemistry, in which no similar classroom activity has been reported so far in the field of chemistry. The end goal is to generate an active learning environment, where students are free to express their viewpoints. Through this activity, lecturers are able to spend more time with each small group to encourage as well as to monitor them. Students are able to find answers based on repeated questionings and support their ideas and answers with evidence. This activity increases the scientific curiosity within the students which in turn consolidates their fundamental understandings in organic chemistry.

In this study, three sets of a story with ten questions were developed as an uncritical inference test. The first story was designed to serve as an introductory activity with the laboratory situation of TLC analysis. The second and third sto-

Story #1. Thin Layer Chromatography

A student walked into an organic chemistry laboratory to carry out an experiment. The required amount of chemicals were measured, namely benzaldehyde, ethyl acetoxyacetate and ammonia, and all the chemicals were added into a round bottom flask. The reaction proceeded until completion. Thin layer chromatography (TLC) analysis was carried out with no additional product observed. The lab assistant was later informed.

Questions

2. This student is a male student.	True	False	Not Sure
3. No chemicals were required in this experiment.	True	False	Not Sure
4. The organic laboratory was part of the building in the chemistry department	True	False	Not Sure
8. This reaction yielded a single isolable product	True	False	Not Sure
9. The end-product was confirmed by spectroscopic analysis	True	False	Not Sure
10. The lab assistant came in later.	True	False	Not Sure

***Figure* 1.** First story with sample questions.

ries are based on first year organic chemistry theory like multi-step synthesis of alkenes and synthesis of acetylsalicylic acid to form a brief story. For example, as shown in *Fig.* 1, Story #1 comprised of an incomplete story which did not disclose that the student who entered the laboratory was a male. Also, the TLC analysis confirmed no additional product other than the starting materials and it was ascertained that the principle of TLC does not involve light; therefore the answers for question 3 and 8 were marked as "False". Along the Story #1, there were no sufficient evidence to support statements 4 and 10, therefore recorded as "Not Sure".

Each story was given to students with ten questions at different day during lecture time, 15 minutes before the class ended as an active learning activity to recapture student attention on each chapter they learnt and assist student to link to the concept they learnt previously and build up to the next chapter. As a case study, three uncritical inference tests were developed and used in this study. Each class activity was divided into two parts, first the individual assessment towards a given case study, and second discussion within their own group. Individual student were required to express their own opinions and to form a consensus answer within the group which was later presented. Throughout this activity, students had to recall what they have learnt, draw inference and communicate with their fellow friends to seek different ideas. In this way, students were able to reformulate their understandings on the subject taught and engage in learning deeper in the science subjects.

RESULTS AND DISCUSSION

Case of Story #1

During the initial phase of the group study on Story #1 (*Fig.* 1), students were keen in exchanging their views. As the discussion progressed, most of the students attempted to make inferences, judgments and assumptions towards the story given and persuade their members to accept their answers without turning to their lecturer to know the background of this activity. After 10 minutes, the group discussion ended and each leader was requested to present their answers and justification. While the group leader read out the answers, the lecturer will question on the justification on the choice of answer they choose. In this way, the lecturer was able to build up an interactive way for knowledge transfer. Along this activity, there were also groups that couldn't reach a consensus answer. Group members were then allowed to give their personal answer. It was optimistic to observe that all the groups participated enthusiastically by voicing out their own deduction and rationale of their choice of answers. From time to time, the lecturer also directed the questions to the floor to seek for different views to promote further intellectual interaction between students. Finally, the lecturer provided the correct answers (*Table* 1) and engaged in a brief discussion with the students by giving his own explanation for each statement/question.

At the beginning of group activity, students discussed actively and chose correct answers for most items like question 1, 2, 3, 4, 6, 8, and 10. However, it was sensible that some groups were unable to pick up the correct premises, especially for the question 5 and 7, between "False" or "Not

***Table* 1.** Response to the questions about Story #1

Questions	Number of groups		
	True	False	Not Sure
1. A male student walked into the laboratory to execute an organic experiment	0	0	7*
2. This student is a male student	0	0	7*
3. No chemicals were required in this experiment	0	7*	0
4. The organic laboratory was part of the building in the chemistry department	0	0	7*
5. The required amount of chemicals was obtained by permission from the laboratory assistant	0	3	4*
6. The store where all the chemicals were kept was opened by a student	1	1	5*
7. After getting the required chemicals, all the starting materials were refluxed with methanol until the complete of reaction	1	4	2*
8. This reaction yielded a single isolable product	0	6*	1
9. The end-product was confirmed by spectroscopic analysis	2	2*	3
10. The lab assistant came in later	1	0	6*

*correct answers

Sure". This was very common as each student had different inference to problem solving and with the aid of this activity, students were able to pick up the correct premises and to learn sharply about a question. For question 9, only two groups recorded "False" as their answer, while majority had chosen "True" and "Not Sure". The lecturer then explained to the student about the definition of "spectroscopic". Overall, the student had a clear mindset of the purpose of the Story #1, which was to learn deeply about a statement and to link the answer they had chosen with the concept they learnt in previous organic chemistry lessons. After the end of discussion on the Story #1, students showed great enthusiasm in the basic organic chemistry subject.

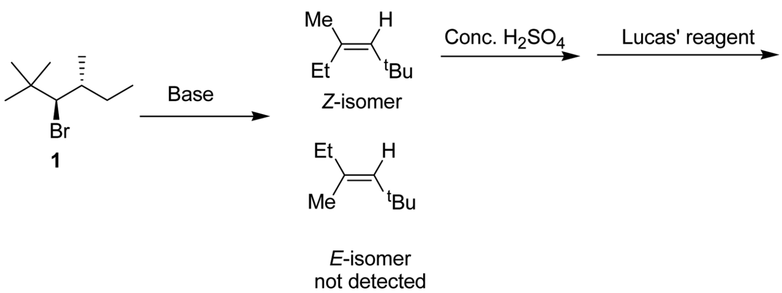
Case of Story #2

The second story (*Fig*. 2) which was specially designed for organic chemistry study requires prior organic chemistry knowledge such as the topics on the conformational analysis, alkane and alkene chapters which were taught in the earlier lectures. A week after these topics were taught, the Story #2 was given to recapture student attention and consolidate student fundamental knowledge before proceeding to the next chapter.

In the Story #2, the lecturer required student to attempt the test in a closed book manner. Students were also required to discuss this test within the group and presented their answer and justification in front of the class as carried out previously. Based on the *Table* 2, it was noticeable that stu-

Story #2. Multi-Step Synthesis of Alkanes

A student walked into the laboratory to perform an organic reaction as illustrated in scheme 1. The reaction of **1** with a strong base yielded only *Z* isomer with no *E* isomer being detected after confirmation with spectroscopic analysis. The isomer *Z* was reacted in concentrated sulfuric acid to yield the subsequent product and was tested with Lucas's reagent, a cloudy solution was formed.



Scheme 1. The multi-step synthesis and Lucas analysis

***Figure* 2.** Story **#2** without questions.

***Table* 2.** Response to the questions about Story #2

Questions	Number of groups		
	True	False	Not Sure
11. A male student walked into the laboratory to execute an organic experiment	2	0	5*
12. This reaction is a stereo-selective reaction	2	4*	1
13. The *E* isomer requires elimination from *syn*-perilanar	3*	2	2
14. This reaction follow Zaitsev's rule	4*	1	2
15. The sodium amide is used as a base in this experiment	1	2	4*
16. The thin layer chromatography is one of the techniques used in spectroscopic analysis	1	4*	2
17. The isomer *Z* has one degree of unsaturation	6*	1	0
18. The *E* and *Z* isomers are configuration isomers	5*	2	0
19. The *E* and *Z* isomers have the same physical properties	2	3*	2
20. The turbidity in Lucas test is due to the formation of organic chloride precipitate	5*	2	0

*correct answers

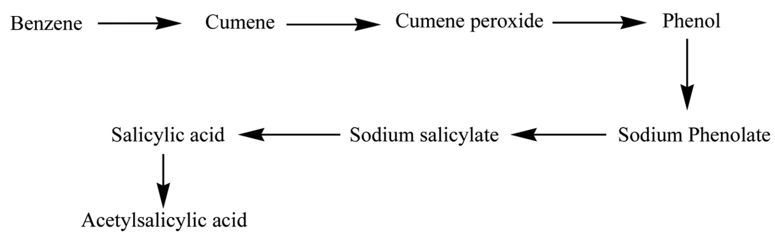
dents found it challenging to attempt most of the questions, yet some students were able to pick up the correct answer. This time they were able to back up their answer with evidence. More than 5 groups chose correct answers for question 11, 17, 18 and 20 which showed that students understood well about degree of unsaturation, *E*- and *Z*- isomers, and turbidity in Lucas test. For questions 11 and 15, student also realized that there was not sufficient information provided therefore recorded 'Not Sure' as their answers. Students that had chosen "False" for question 12 was able to explain the *Z*- isomer is much more favorable compared to *E*- isomer through *anti*-elimination in Newman projection. Last but not least, most students were able to relate the experiment they have conducted with theory, which was evident in question 20. The rest recorded "True" for questions 13, 14, 17, 18 and 20 and 'False' for questions 12, 16 and 19. On the other hand, there were also moments when students were unable to recall the facts in this closed book activity. For questions 13 and 19, only three groups answered correctly. Some groups feedback that they were unsure whether *E*-isomer is produced *via syn*-periplanar or whether the configuration isomers have the same physical properties, therefore recorded "Not Sure" as answer. The inability of students to correctly answer these questions is in agreement with a study which revealed that students were only able to capture 20–40% of the main content of a lecture and without doing regular revision on the lecture handouts, student knowledge storage will decline to 10% after 3 weeks.[26,27] The lecturer then advised the students to revise their lecture handout within 36–48 hours after a lesson for long term memory storage.

Case of Story #3

The third story (*Fig*. 3) was given to the groups with 10 questions shown in *Table* 3. This questionnaire was formed based on the synthesis of aspirin and prior knowledge on alcohol and benzene chapter was required. Undoubtedly, the acetylsalicylic acid consists of two functional groups,

<u>Story #3. Synthesis of Acetylsalicylic Acid</u>

Acetylsalicylic acid is widely used as an analgesic to relieve pain and inflammation in patients. One of the possible routes to the synthesis of acetylsalicylic acid is illustrated in Scheme 2.



Scheme 2: Synthesis of Acetylsalicylic acid *via* benzene

***Figure* 3.** Story #3 without questions.

***Table* 3.** Response to the questions about Story #3

Questions	Number of groups		
	True	False	Not Sure
21. Acetylsalicylic acid has two functional groups	7*	0	0
22. Acetylsalicylic acid is an ester derivative of salicylic acid	7*	0	0
23. The side-product from cumene peroxide to phenol is acetone	6*	1	0
24. The carboxylation reaction of sodium phenolate to sodium salicylate is called Kolbe-Schimitt reaction	4*	1	2
25. Carbon dioxide is a nucleophile in Kolbe-Schimitt reaction	3	2*	2
26. Kolbe-Schimitt reaction afforded *ortho*-hydroxy benzoic acid as the only product	2	3*	2
27. Acetylsalicylate is formed by reacting salicylic acid with acetic anhydride	4*	1	2
28. The by-product of the acetylsalicylic acid formation is a compound with chemical formula $C_2H_4O_2$	5*	0	2
29. Aspirin is salicylic acid	2	4*	1
30. Acetylsalicylic acid is a stronger acid compared to salicylic acid	2	3*	2

*correct answers

therefore the answer for question 21 was recorded as "True". In addition, phenol is the nucleophile in the Kolbe-Schimtt reaction (Question 25) and this reaction afforded two products, which are the ortho- and para-hydroxy benzoic acids (Question 26). Also, the commercial name for acetylsalicylic acid is aspirin (Question 29) and acetylsalicylic acid is a much weaker acid compared to salicylic acid (Question 30), thus questions 25, 26, 29 and 30 were recorded as "False". The answer for the rest of the questions is recorded as "True".

A closed book test was initially conducted in this test, however, due to the Kolbe-Schmitt reaction was not covered in the syllabus, the lecturer provided the reaction condition and starting material on the white board without giving information on the end product as supplementary information to aid student in find out the mechanism of this reaction. Students soon realized that knowledge on the chemical structures of benzene and its intermediates are important to predict the synthetic pathway of acetylsalicylic acid, therefore students strived to recall and sketched the structures of each intermediate compounds as shown in the synthetic scheme. During the presentation of answers, the lecturer invited group leaders to provide reasoning for the choice of answer and the possible mechanism of each product.

Based on *Table* 3, students were found to have sound understanding about basic characteristics of acetylsalicylic acid such as functional groups and derivatives. This was evident when students were able to mention that acetylsalicylic acid contains two function groups, namely the carboxylic acid and ester functional groups. However, some students failed to identify the nucleophile and electrophile and thus were unable to work through the mechanism of Kolbe-Schmitt reaction, resulting to only two groups recorded "False" for question 25. The lecturer then pointed out to the students that the starting material phenolate ion provided on the white board served as the nucleophile whilst the carbon dioxide as the electrophile. Also, only three groups of students managed to correctly answered question 26, when in fact the Kolbe-Schmitt reaction affords two possible products, which is the *ortho*- and *para*- salicylic acid as the hydroxyl group of phenol served as activator at positions *ortho*- and *para*-. For question 30, again only three groups submitted the correct answer which means more than half of students failed to compare the acidity between acetylsalicylic acid and salicylic acid. The lecturer then made a hint on the white board by comparing the chemical structures of acetylsalicylic acid and salicylic acid with their respective acidic protons. Students were overwhelmed that actually acetylsalicylic acid has only one proton on the carboxyl group, while the salicylic acid has two protons, one on the carboxyl group and the other on the hydroxyl group. On the whole, most of the groups were able to work through the rest of the questions and provided valid justifications.

Students' Feedback to the Activity

After finishing the third activity, students' perceptions on the impact of uncritical inference test activities were surveyed. The responds toward the activity were collected as shown in *Table* 4, and overall feedback was highly positive. All of 88 respondents had feedback that this activity could enhance cooperative learning in organic chemistry (M=3.45) and as well to enhance their communication skill during the activity (M=3.32). 86 of the respondents agreed that this activity could be a useful activity to enhance their problem solving by recalling previous knowledge (M=3.55). Lastly, 82 of the respondents said that they would like to attempt the similar kind of activity again in this course (M=3.45).

***Table* 4.** Response towards the case study (N=88)

Question	Rate*				M	SD
	1	2	3	4		
Rate the effectiveness of this activity in cooperative learning	0	0	48	40	3.45	0.50
Rate the effectiveness of this activity in problem solving	0	2	36	50	3.55	0.54
Rate the effectiveness of this activity in enhancing communication skill	0	0	60	28	3.32	0.47
Rate whether you would like to work in this type of activity again	0	6	36	46	3.45	0.62

*1= Poor ; 2= Moderate; 3= Good; 4= Excellent

CONCLUSION

The purpose of this research was to invoke deeper thinking among students in the subjects of college organic chemistry by engaging them in the uncritical inference test. For this purpose, three sets of uncritical inference test with a short story and questions were designed and applied to Malaysian college organic chemistry course. The lecturer actively interacted with students during group discussion and guided their learning. After three times of case studies, students expressed positive feedback on the impact of this activity on group work and skills. As a result, the designated classroom activity which incorporated the uncritical inference test with organic chemistry knowledge showed possibility to contribute meaningfully towards the goal to develop higher cognitive skills among students in the subject of organic chemistry. This simple activity that consisted of questions and answers seemed to encourage students to question continuously and think critically on the lecture notes given. This is particularly important as this activity can serve as a bridge to convey difficult theories especially in the investigation on the mechanism of organic reactions which is the core of organic chemistry which require a thorough conceptual understanding rather than facts memorization. To further prove the effectiveness of this test, activity such as reflective journals could be implemented beforehand to track the understanding of students in organic chemistry. Qualitative data such as interactions within a group and students' reflective journals on this activity[26,27] will be collected and reported in the near future.

Also, the finding of this activity suggests that active learning environment is very important to nurture students' question-asking capability. With the introduction of more active learning environment, such as the activity that we conducted, they will enhance students' critical thinking skills and thereby producing graduates that have independent problem-solving and decision-making abilities. We believed that this activity can be applied to other discipline area to promote cognitive development and equip student with problem solving capability.

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