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INNOVATION IN ACTION: TURNING IDEAS INTO REALITY

Chapter 3
S_N2 5E Model 2.0

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ABSTRACT
Based on reflections from past lessons, the *Fantastic Excel* group found that students had difficulties in writing the S_N2 (bimolecular nucleophilic substitution) mechanism learned in organic chemistry because it is difficult to visualise the processes that occur at the molecular level in three dimensions. Students also experienced difficulty in comparing the reactivity towards $_{SN}2$ reactions among various classes of haloalkanes. To address this learning problem, a lesson study was conducted on 21 students in the F3T3 practicum. Two cycles were carried out to improve the related teaching and learning activities and materials, resulting in the production of the S_N2 5E Model 2.0, which is a digital tool containing links to various activities such as animated videos, online "hands-on" simulations and interactive digital gameshow-oriented exercises. S_N2 5E Model 2.0 assists students in learning the S_N2 mechanism based on the 5E Model, which includes 5 phases of learning, namely Engage, Explore, Explain, Elaborate and Evaluate. S_N2 5E Model 2.0 also enables students to carry out self-directed learning and can be utilised as a teaching aid by lecturers in tutorial classes. Through S_N2 5E Model 2.0, students can actively involve themselves in activities that explore, construct and deepen the understanding of the S_N2 mechanism at a submicroscopic level and subsequently strengthen the mastery of the symbolic domain in writing the mechanism using correct arrows and molecular structural formulas. The learning strategy used in this innovation is in line with 21st-century learning and is suitable for future education. This innovation project has been successfully disseminated at the college level and subsequently to other colleges.

Key Words: S_N2 5E Model 2.0, S_N2 mechanism, 5E Model

1. INTRODUCTION

To prepare students to meet the demands of the future, learning methods must change from conventional methods that often emphasise memorisation practices to methods that can equip students with critical thinking skills, problem-solving skills and exploratory learning skills. Therefore, the *Fantastic Excel* innovation project has used a learning approach based on the 5E Model (Bybee et al., 2006) which includes 5 phases of learning (Engage, Explore, Explain, Elaborate and Evaluate) as described in Table 1.

Table 1. Description of the 5E Model Phase Functions

Phase		Description
Engage	▪	Stimulates students' interest and curiosity by linking the teaching and learning topic with past learning experiences.
Explore	▪	Allows students to interact with the concepts being learned through hands-on activities to generate new knowledge and skills.
Explain	▪	Provides opportunities for students to explain a concept according to their understanding and enables lecturers to provide further explanation to guide students to deepen their understanding of the concept.
Elaborate	▪	Enables students to apply what they have learned to a new situation to enhance their understanding of the concept.
Evaluate	▪	Encourages students to conduct self-assessment of their understanding of concepts and mastery of specific skills, while lecturers can assess students' progress in achieving learning objectives.

2. ISSUE AND PROBLEM STATEMENT

According to Johnstone (2006), abstract concepts in chemistry require thinking at three levels, namely macroscopic (things that can be seen with the naked eye), submicroscopic (things that cannot be seen with the naked eye such as atoms, molecules and ions) and symbolic (the use of symbols, formulas and chemical equations). Abstract concepts in organic chemistry also encompass these three levels or domains (Dwyer & Childs, 2017). Among these abstract concepts is the organic reaction mechanism. The organic reaction mechanism is a detailed account of electron movement during the breaking and forming of bonds that occur in a reaction (Wade & Simek, 2017). The writing of reaction mechanisms involves the symbolic domain. Students need to use appropriate chemical symbols and structural formulas to represent the reagents and organic molecules that react, in addition to using arrows to represent the movement of electrons. The submicroscopic domain includes the depiction of covalent bond formation involving the attack by an electron-rich species, i.e. a nucleophile, on an electron-deficient species. The macroscopic domain is largely learned in practical classes through observations made when organic compounds react with reagents. However, most organic reactions are not learned in practical classes. Therefore, students' understanding of these reactions depends solely on learning that involves the symbolic and submicroscopic domains.

Based on reflections from past teaching and learning, we found that students experienced learning difficulties for the S_N2 (bimolecular nucleophilic substitution) mechanism in Topic 7: Haloalkanes. The S_N2 mechanism is difficult for students to understand even though it only involves one step because students need to visualise in three dimensions the process of nucleophilic attack on the haloalkane, the formation of the transition state and the configuration of the final product. It was found that 45% of students were unable to compare the reactivity of haloalkanes from various classes towards S_N2. Results from random interviews with students showed that students tend to memorise the S_N2 mechanism which is considered different from other topics because it has a rate-determining step and a transition state. 30% of students were not proficient in using arrows to show nucleophilic attack on the haloalkane molecule while 20% were unable to draw the transition state and the inverted configuration of the resulting molecular structure. These errors are similar to the common errors listed in the *Laporan Kerja Calon* (Matriculation Division, 2023) for the achievement of

Kolej Matrikulasi Negeri Sembilan (KMNS) students in the Matriculation Programme Semester Examination (PSPM) Chemistry 2 SK025 in the 2022/2023 session.

3. OBJECTIVES

The objectives of the innovation were set as follows:

1. 100% of students can write the S_N2 mechanism correctly for the reaction of haloalkanes with
   ^-OH and ^-OR ions.
2. 100% of students can compare the reactivity of different classes of haloalkanes towards S_N2.

4. SOLUTION STRATEGY, INNOVATION AND NOVELTY

The *Fantastic Excel* group produced an innovation project called S_N2 5E Model 2.0 to actively involve students in activities that explore, construct and deepen the concepts of the S_N2 mechanism at a submicroscopic level and subsequently strengthen the mastery of the symbolic domain in writing the mechanism using correct arrows and molecular structural formulas. Two cycles were carried out in a lesson study (Figure 1) involving the Focus, Improve and Share procedure (Ministry of Education Malaysia, 2019) to produce the S_N2 5E Model 2.0.

Figure 1. Lesson Study Cycle

Figure 2. S_N2 5E Model 2.0

S_N2 5E Model 2.0 is a digital learning tool that contains links to various teaching and learning materials and activities for learning the $_{SN2}$ mechanism (refer to Figure 2). The sequence of content in S_N2 5E Model 2.0 is based on the 5E Model, starting with an animated video introducing the S_N2 mechanism and followed by a role-play video, an S_N2 explanation video using ball and stick models, online hands-on simulations and finally, interactive exercises that assess students' level of mastery. The interactive exercises were developed using the Wordwall application and are gameshow-oriented, providing feedback to students immediately after they answer a question. The S_N2 5E Model 2.0 innovation has been registered for copyright under the Intellectual Property Corporation of Malaysia with registration number LY2024M03160.

5. TARGET GROUP

Our target group consisted of 21 KMNS students (10 male and 11 female) from the F3T3 Physical Science Stream Practicum for the 2023/2024 session.

6. DATA COLLECTION AND DATA ANALYSIS

A questionnaire containing five items involving the Likert Scale (1-5) and one open-ended question was used to collect student feedback after the intervention in Cycle 1. Data analysis showed that three items obtained a mean score of 5.00 and two items scored 4.95 (refer to

Table 2). This indicates that students gave very positive feedback on the activities and digital application (S_N2 5E Model) used in learning the S_N2 mechanism.

Table 2. Analysis of Feedback on S_N2 Mechanism Teaching and Learning

Questionnaire Item	Mean	S. D.
The activities carried out are suitable for achieving the learning outcomes.	5.00	0.00
The activities carried out enhance my knowledge and understanding of S_N2.	4.95	0.22
The activities carried out increase my interest in learning the S_N2 mechanism.	5.00	0.00
The activities carried out are interactive and enjoyable.	4.95	0.22
The digital application used is suitable for training me to write the S_N2 mechanism.	5.00	0.00
Overall	4.95	0.12

Pre-test and Post-test 1 were conducted to assess students' mastery of the S_N2 mechanism before and after the intervention. The Pre-test and Post-test 1 consisted of one structured question and five objective questions with a total score of 10, to be answered within 20 minutes. After the intervention, students' achievement with a pre-test mean score of 5.24 and standard deviation of 2.59, which is a Moderate level, increased to a Post-test 1 mean score of 8.52 and standard deviation of 1.63, which is an Excellent level. The learning objectives were achieved, i.e. the percentage of students who successfully wrote the S_N2 reaction mechanism correctly and compared the reactivity of different classes of haloalkanes towards S_N2 increased from 85.7% (28.6% Moderate level, 38.1% Good level and 19.0% Excellent level) to 100% (23.8% Good level and 76.2% Excellent level).

7. INNOVATION IMPROVEMENT

The improvement in student achievement in the Post-test after the intervention proves that the activities and materials developed based on the 5E Model are effective in enhancing students' mastery of the S_N2 mechanism. However, several suggestions for improvement from group members and expert reviewers were taken into account to refine the S_N2 5E Model, resulting in the S_N2 5E Model 2.0. Among the improvements made to the innovation were providing clearer instructions for the activities, updating the content of the linked videos, and modifying the gameshow format in the Wordwall application so that marks were awarded based only on correct student answers and not the time taken to answer.

8. REFLECTION ON THE SUBSEQUENT CYCLE AND IMPROVEMENTS

Subsequently, Cycle 2 of the lesson study was conducted on F3T3 students using S_N2 5E Model 2.0. Table 3 shows that both Post-tests 1 and 2 achieved a 100% passing rate. However, the students' mean score for Post-test 2 in Cycle 2 (mean = 8.86, s.d = 1.31) was better than the mean score for Post-test 1 in Cycle 1 (mean = 8.52, s.d = 1.63). This indicates that S_N2 5E Model 2.0 used in Cycle 2 is more effective in achieving the set learning objectives.

Table 3. Comparison of Pre-Test and Post-Test Scores for Cycles 1 and 2

		Percentage (%)		
Achievement Level	**Marks**	**Pre-test**	**Post-test 1**	**Post-test 2**
Fail	0 - 2	14.3	0.0	0.0
Moderate	3 - 4	28.6	0.0	0.0
Good	**5 - 7**	**38.1**	**23.8**	**14.3**
Excellent	**8 - 10**	**19.0**	**76.2**	**85.7**
Mean (Standard Deviation)		5.24 (2.59)	8.52 (1.63)	8.86 (1.31)

9. CONCLUSION AND DISSEMINATION

S_N2 5E Model 2.0 is more user-friendly and can be used by students for self-directed learning, as well as being utilised by lecturers according to their respective creativity both inside and outside the classroom. Students' mastery of the submicroscopic domain facilitates their acquisition of the skill to write S_N2 mechanisms involving the symbolic domain. The learning strategy used in this innovation is aligned with 21st-century learning. S_N2 5E Model 2.0 also received endorsement from the Head of the Centre for Chemical and Environmental Studies, Universiti Teknologi Mara Negeri Sembilan Branch, Prof Madya Ts ChM Dr Sheikh Ahmad Izaddin Sheikh Mohd Ghazali, who stated that this innovation is suitable for use in enhancing the understanding of school, matriculation and university students in grasping the basic concepts of the S_N2 mechanism. Following this, S_N2 5E Model 2.0 was disseminated at the college level and subsequently to other colleges.

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