

The Teaching and Learning of Chemical Kinetics Supported with MS Excel

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Students in 12 secondary schools in three states of Malaysia were taught to use worksheets on the chemical kinetics topic which had been pre-created using the MS Excel worksheets. After the teaching, an opinion survey of 612 Form Six students from these schools was conducted. The results showed that almost all the students felt that MS Excel provided a very useful platform to assist students conceptualise experimental kinetic data. They opined that the use of MS Excel should be used to teach a wider range of chemistry topics and that the use of such an approach had increased their appreciation for chemical kinetics. There is a significant difference of opinion towards this approach between male and female students but there is no significant difference among the different races. All the 24 teachers in the study also gave very positive comments about the approach. They realised that the use of MS Excel had stimulated and motivated students to learn chemistry.

Keywords: MS Excel, Chemical reaction, Reaction kinetics, Rate law, Order of reaction

Introduction

Rapid advances in information and communication technology (ICT) has brought about a major shift in the education paradigm that promises advantages over conventional learning systems (Baxi, 2008; Mai, 2001; MOE Singapore, 2008; Mohd Arif, Mohd Jasmy & Rosnaini, 2005; Oyelekan & Olerundare, 2009; Rosnaini, Mohd Arif & Jalalludin, 2011; Tinio, 2007). This has very important implications in chemistry education as well (Barak, 2007; Hollingworth, 2002; King, 2011; Pekdag, 2010; Soon, 2003). One main advantage of using MS Excel is that it is available in almost all personal computers running on the Windows operating system in Malaysian schools as it is included as standard software in the MS Office. Besides, MS Excel has a user friendly and highly functional graphical user interface. The ability to write custom code in languages such as Microsoft's Visual Basic for application has also made MS Excel a very powerful tool. Beginner users can easily master its usage with its user friendly features. Users can also modify the spreadsheet according to their needs.

The use of ICT and MS Excel in teaching and learning has been extensively reported in education journals. For example, Aksela's study (2005) which involved 88 students showed that a rich learning environment through computer-assisted inquiry can support meaningful chemistry learning and improve students' higher-order thinking. A study done by Norasiken and Halimah (2007) to investigate the effectiveness of virtual laboratory methodology for chemistry learning indicated that this approach could increase students' and teachers' understanding in chemistry whilst King (2011) reported that the ICT-integrated environment learning strategy can increase students' understanding of chemistry concepts and enhance students' performance. Sinex (2008) developed an interactive MS Excel spreadsheet, *The Boyle's Law Simulator*, where students can investigate experimental error in the virtual realm of a spreadsheet and reported that students were engaged in higher-order thinking and numerous science process skills as they worked through the simulation. MS Excel was also successfully used in the study on kinetics. For example, Bruist (1998) used MS Excel in his study on the use of spreadsheets to simulate enzyme kinetics to display the changes in the amount of carbon and nitrogen with time. The graphical functions in MS Excel was able to illustrate the kinetics of enzyme and the mechanism of reaction as well as relate chemical phenomena with mathematical equations well. Denton (2000) used MS Excel Solver to analyze the experimental data from kinetics investigations where students were asked to determine the best fit

values of V_0 , V_∞ and k using a curve fitting solver. Brown (2001) introduced MS Excel spreadsheet to college students with the purpose of increasing their understanding and appreciation of solubility. Lim (2005) showed how the MS Excel spreadsheet could help in the simulation of linear-molecule spectra to explore the dependence of rotational bond spacing and contours on average bond lengths in the initial and final quantum rotational states. Arifin (2012) developed the *GChem* software using MS Excel Visual Basic for Application (VBA) program to assist chemistry students at faculty of applied sciences in learning electrochemistry and acid-base calculations. In the accompanying survey, the students found this application helpful in their study of electrochemistry.

Teaching and Learning Chemical Kinetics in High School Education

Chemical kinetics or reaction kinetics is the study of the rate of a chemical reaction. Reaction rate can be defined as the increase in molar concentration of the product of a reaction per unit time or the decrease in molar concentration of a reactant per unit time (Ebbing, 1993). Loh and Sivaneson (2004) defined rate of reaction as the change in concentrations of the products at a given time. Essentially, the rate of reaction for a particular reaction can be defined as how fast the reaction takes place. Analysing the factors influencing the reaction rate at different reaction conditions will enable chemists to have a better understanding on how a reaction occurs. Experimental data from kinetics investigations can be analyzed using MS Excel. In the Form Six syllabus of Malaysian high schools, the most essential task in the study of kinetics is for the student to understand the effects of the concentration of a reactant $[A]$ and the rate constant (k) on a reaction rate. Students are expected to understand the graphical characteristics of zero order, first order and second order reactions and to solve chemical kinetics problems.

The Purpose of the Study

The use of ICT tools in enhancing teaching and learning of chemistry in Malaysian schools is still minimal (Hee & Norahidah., 2001; Khalijah, Lilia, Kamisah & Tamby Subahan, 2001; MOE Malaysia, 2010; Mohd Arif et al., 2005; Moses, Wong, Kamariah, & Rosnaini, 2012; Rosnaini et al., 2011). From the literature, attempts to use ICT to teach chemistry in Malaysian schools mainly involve the use of pre-prepared software which does not always meet the teacher's need (MOE Malaysia, 2010). Hence, teachers should be made aware

of and encouraged to create their own teaching materials using existing tools such as MS Excel. This study intends to convince chemistry teachers how to implement some of the primary spreadsheets visualisation techniques using MS Excel to create interactive and animated graphic educational models for the topic on reaction kinetics.

The Study

This study involved 612 Form Six students and 24 chemistry teachers from 12 government co-education secondary schools in three Malaysian states namely Negeri Sembilan, Melaka and Johor. Two workbooks were created namely, the *Chemical Kinetics 1* workbook (Figure 1) which could be used by teachers as a teaching aid in the classroom and the *Chemical Kinetics 2* workbook (Figure 2) for students to solve chemical kinetics problems as a take home exercise. All the teachers involved in this study were given a briefing and demonstration by the researcher on the use the workbooks.

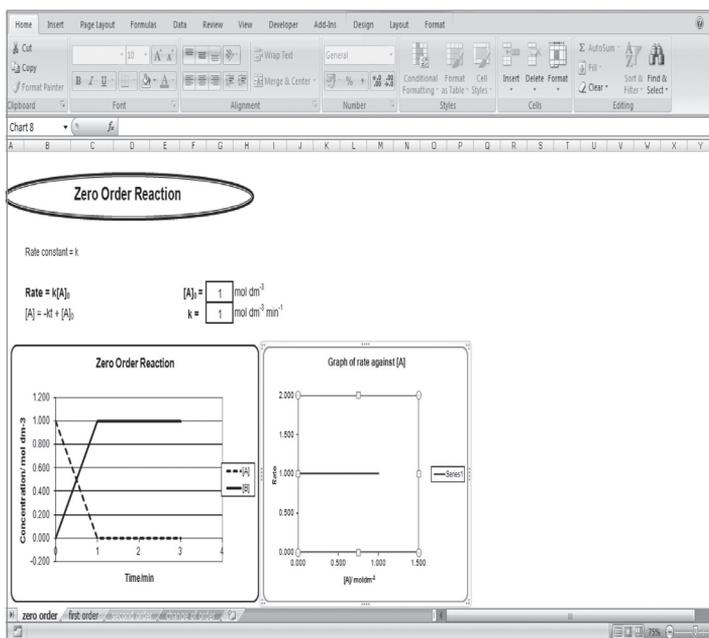


Figure 1. Chemical Kinetics 1 workbook.

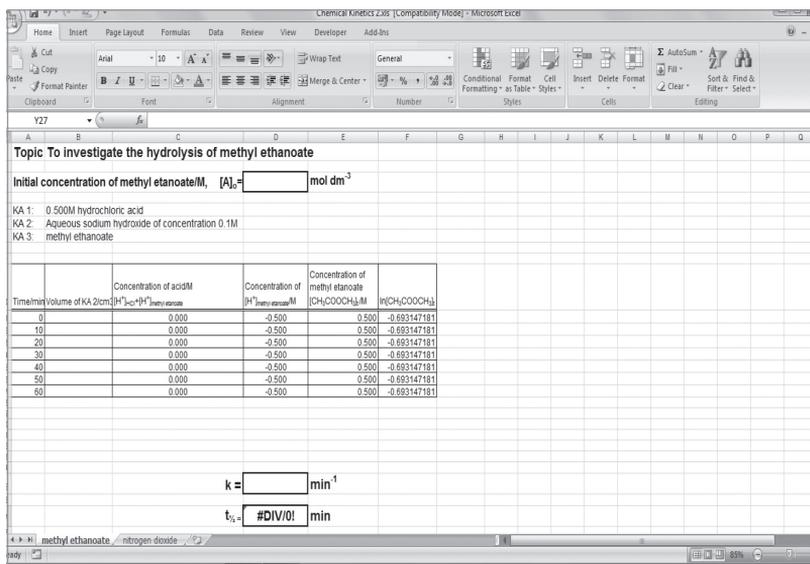


Figure 2. Chemical Kinetics 2 workbook.

There are four worksheets in the *Chemical Kinetics 1* workbook: the *zero order* worksheet, *first order* worksheet, *second order* worksheet and *change of order* worksheet. All the graphs in these worksheets were created using the chart wizard function in MS Excel. This workbook can be used as a teaching aid when introducing orders of reaction and to show their students how $[A]_0$ or the value of rate constant, k , may affect the reaction rate in the classroom (4-5 periods of lesson). When a teacher/student changes the value of $[A]_0$ or k in any of the worksheets by typing in a new value in the boxes provided, the graph will change interactively. Students can observe the changes of graphs immediately and obtain a clearer picture on how a certain factor influences the kinetics of a reaction. The frequency of using this workbook depends on individual teacher's need which is based on their students' ability to understand. The *Chemical Kinetics 2* workbook was created to display the experimental data to help students determine the order of a reaction, the values of k and of $t_{1/2}$. In this study, the hydrolysis of methyl ethanoate was used as an example to investigate the first order

reaction and the decomposition of nitrogen dioxide for the second order reaction. Students were required to carry out an experiment to investigate the hydrolysis of methyl ethanoate in the laboratory during their laboratory sessions whilst the data on decomposition of nitrogen dioxide were given to the students. From the experimental data, students were then required to prepare graphs using the chart wizard functions in the spreadsheet created. From the graphs, students could then determine the order of reaction and the value of k . The spreadsheet automatically calculates the value of $t_{1/2}$ once the student type in the value of k obtained. This activity can be done at home or in the school ICT lab.

The Perception Survey

A survey was conducted to obtain the perception of chemistry teachers and Form Six chemistry students after they had used this new approach. The profile of respondents is shown in Table 1. The profile shows that there was a predominance of female teachers in these schools. Out of the 24 teachers who were involved in this study, 16 (66.7%) were female and 8 (33.3%) were male. There were 359 (58.7%) female students and 253 (41.3%) male students. Among the 24 teachers, 14 (58.3%) were Malay and 10 (41.7%) were Chinese. The breakdown according to ethnicity shows that there were 450 (73.5%) Chinese students, 103 (16.8%) Indian students, 56 (9.2%) Malay students and 3 (0.5%) students of other ethnicity. The demographic breakdown of the survey respondents represents a typical Malaysian Form Six classroom in a government secondary school.

Table 1
Sample Profile

	Background	Frequency	Percentage
Gender	Male	8	33.3
	Female	16	66.7
Teacher	Male	253	41.3
	Female	359	58.7
<hr/>			
Race	Malay	14	58.3
	Chinese	10	41.7
	India	-	-
Student	Malay	56	9.2
	Chinese	450	73.5
	India	103	16.8
	Others	3	0.5

The Instrument

A validated questionnaire (Nor Liya, 2003) (see Appendix A) for students and another one for teachers (Appendix B) were used to obtain the respondents' perceptions to this teaching approach within the time frame of July 2009 to May 2010 depending on the school's schedule in teaching this topic. Data collected was analyzed using SPSS 12.0.

The students' questionnaire was divided into two parts, part A and part B. The objective of part A is to collect the biodata of students such as gender, ethnicity, educational background and level of computer knowledge whilst part B consists of 15 questions to gauge students' perceptions towards the effectiveness and suitability of MS Excel in the teaching and learning of chemical kinetics. Similarly, the teachers' questionnaire was also divided into two parts where part A was related to the biodata of the teachers and part B was about the teachers' perceptions or comments on using MS Excel in the teaching and learning of chemical kinetics. Students/teachers have to answer either "Yes" or "No" to each question.

Data Analysis

From the data collected, 612 students' and 24 teachers' perceptions towards this new approach in the teaching and learning of chemical kinetics were analysed and presented in the form of percentages (Figure 3 & 4). The percentages were calculated based on the number of yes responses for each item in the questionnaire.

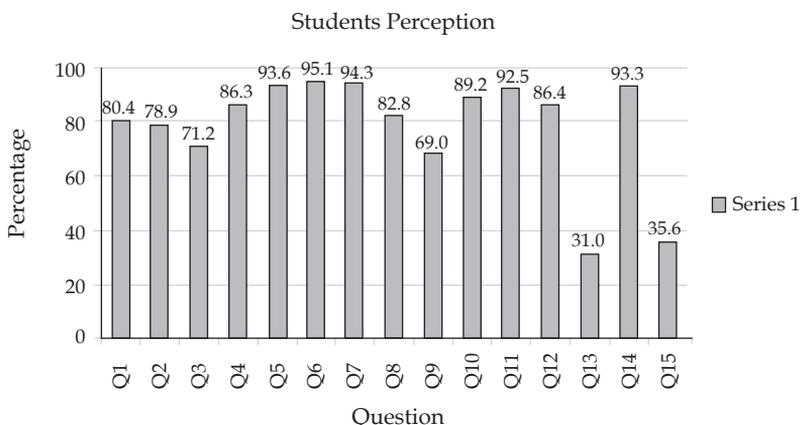


Figure 3. Graph of students' perception towards the new teaching approach.

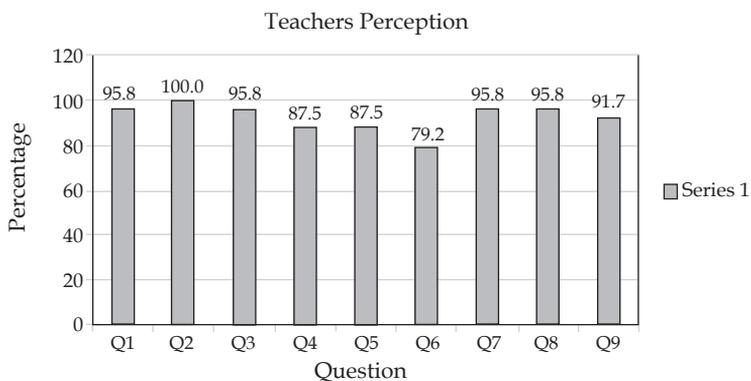


Figure 4. Graph of teachers' perception towards the new teaching approach.

Chi-Square test was used to observe the difference in students' and teachers' perceptions to this approach between two different genders (Table 2) and among different races (Table 3).

Table 2

Chi-Square Test to Observe the Students' Perception towards Using MS Excel in Teaching and Learning Chemical Kinetics between Different Genders

	Value	df	Asymp. Significant value (2-sided)
Pearson Chi-Square	25.976	15	0.038*
Likelihood Ratio	27.975	15	0.022
Linear-by-Linear Association	12.374	1	0.000
N of Valid Cases	612		

*Significant P<0.05

Table 3

Chi-Square Test to Observe the Students' Perception towards Using MS Excel in Teaching and Learning Chemical Kinetics among Different Races

	Value	df	Asymp. Significant value (2-sided)
Pearson Chi-Square	36.275	45	0.820
Likelihood Ratio	42.073	45	0.597
Linear-by-Linear Association	0.051	1	0.821
N of Valid Cases	612		

*Significant P<0.05

Findings

It was found that students show positive attitude towards this new teaching approach. Based on the responses to question 7 in the questionnaire, more than 90% of all students strongly agreed that MS Excel has provided a convenient and easy platform to plot various graphs and to determine the order of reaction. From question 6, it was found that almost all (95.1%) of the students said that through MS Excel, charts can be easily created within a very short time. This will allow them to have more time to discuss chemical

problems as compared to spending much time plotting the graphs manually. As shown from the responses to question 8, a great majority (82.8%) of the students were interested in and enjoyed the chemistry lessons using this new approach and 89.2% (Question 10) agreed that MS Excel has many advantages which can help in the teaching and learning of chemistry. For example, the language and menu in Excel worksheets is easy to understand and user friendly, charts can be presented accurately within a short time. Students can thus save a lot of time in solving chemical problems such as the determination of rate constant, order of reaction and calculation of $t_{1/2}$. Interactive features such as the simulation of graphs in the program also helped students understand chemical kinetics concepts better and create interesting learning environment. From question 11, it was shown that 92.5% of the students said that the MS Excel should be used for a more topics in chemistry. In addition, most of the students (>93%, from question 14) agreed that the language and menu in MS Excel is easy to understand and user friendly even for an elementary learner.

Though almost all students showed positive attitude towards this new teaching approach, the result of Chi-Square test (Pearson Chi-Square) in Table 2 ($\chi^2=25.976$, $df=15$, $p<0.05$) shows that there is a significant difference of opinion towards this new teaching approach in chemistry lessons between male and female students. This could be due to the natural tendency of male students to favour the use of ICT more as observed by Catherine (2008), Kubiato, Usak, and Yilmaz (2010) and Kubiato (2010). The Chi-Square test (Pearson Chi-Square) in Table 3 ($\chi^2=36.275$, $df=45$, $p>0.05$) shows that there is no significant difference in students' opinion towards this new teaching approach in chemistry lessons among students of different ethnicity. The results of the study showed that all students appreciated the use of the EXCEL as a tool for the analysis of experimental kinetics data. They were very satisfied with this innovative method of teaching and learning chemical kinetics.

All the teachers involved in the study also gave very positive comments about this new approach (Figure 4). They were aware that MS Excel is an attractive program and more than 95.0% of them agreed that MS Excel is able to motivate students. During the learning process, students were observed to be more actively involved and the interactive feature of the program enhanced their understanding on the lessons. Furthermore, 95.8% of the teachers agreed

that the language used in MS Excel is easy to understand and that they look forward to use the program in the future.

Discussion and Conclusion

The use of MS Excel in teaching and learning provides a very convenient platform to assist students conceptualise experimental kinetic data. Simulation of graphs using random rate constants and orders of reaction could give a better understanding to students. In addition, the determination of the rate constant, order of reaction and calculation of $t_{1/2}$ become easy and fast. The activities exposed students to an alternative way of learning chemical kinetics and allows students to analyse experimental data with deeper understanding. In addition, the MS Excel worksheets created can also help them to develop their mathematical, computer and graphing skills. Thus, the nurturing of mathematical, computer and graphing skills is directly addressed via the use of these worksheets. Responses and feedback from teachers and students involved in this project were very encouraging. Although the spreadsheets created in this study were much simpler as compared to other studies on reaction kinetics (Bruist, 1998; Denton, 2000; Moreira, Martin, & Elvas-Leitao, 2006), the positive responses from both students and teachers show that this approach is reliable.

This study had made teachers aware that the use of EXCEL is stimulating and is able to motivate students to learn chemistry. This in turn, will certainly promote their further interest in exploring EXCEL's pedagogical potential in teaching and learning of chemistry. It is envisaged that this approach will be widely adopted by many school teachers and the use of EXCEL could be encouraged to a wider area of chemistry by creating effective and entertaining worksheets, thus enhance teaching and learning of chemistry in schools and promote greatly the quality of chemical education in Malaysia.

The challenge ahead now is shifting from predominantly teacher-centered pedagogies to more learner-centered pedagogies in class because the majority teachers in the country are still not comfortable with using ICT as a connection and reconstruction tool to expand the learning opportunities of their students. It is hoped that this awareness may prompt teacher training department in Ministry Of Education to conduct professional development programs for chemistry teachers in the country. They should be introduced and trained to excel in using EXCEL spreadsheet to assist them in achieving

excellency in pedagogical approach for quality education. Since the study was conducted in only three states in Malaysia, it may not be valid to generalise the results to apply the whole population of Lower Six students. Hence, it is recommended that other similar studies be conducted involving a bigger sample from different locations of the country. Further, the application of MS Excel in organic chemistry could be further explored to produce more effective and meaningful simulation to enhance the study of the subject.

With elementary knowledge of MS Excel, chemical kinetics workbooks were created and tested in schools. Feedback from this study was able to verify the contention that MS Excel does stimulate and improve the teaching and learning of chemical kinetics. In Malaysia, this will certainly generate further interest in exploring the pedagogical potential of MS Excel in the teaching and learning of chemistry.

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Appendix A

Evaluation Form For Teaching Kinetic Chemistry Using MS Excel Program [Student]

PART A : Respondent Background

Instruction: Please tick '☐' in the blank provided

1	Gender	Male	<input type="checkbox"/>	Female	<input type="checkbox"/>
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2	Race	Malay	<input type="checkbox"/>	Chinese	<input type="checkbox"/>
		India	<input type="checkbox"/>	Others	<input type="checkbox"/>
				(Please state)	<input type="checkbox"/>

3	Gred for chemistry in SPM	1	<input type="checkbox"/>
		2	<input type="checkbox"/>
		3	<input type="checkbox"/>
		4	<input type="checkbox"/>
		5	<input type="checkbox"/>
		6	<input type="checkbox"/>
		7	<input type="checkbox"/>
		8	<input type="checkbox"/>
		9	<input type="checkbox"/>

4	Level of computer knowledge	Very Poor	<input type="checkbox"/>
		Poor	<input type="checkbox"/>
		Moderate	<input type="checkbox"/>
		Good	<input type="checkbox"/>
		Very Good	<input type="checkbox"/>

5	Do you have personal computer at home	Yes	<input type="checkbox"/>
		No	<input type="checkbox"/>

- 6 Have you attended any computer course before?
If "Yes" Please state the course you have attended

Yes	
No	

- 7 Have you ever use computer to solve any problem or task given by your teacher?
If your answer is "Yes" Please state what program have you used

Yes	
No	

PART B:

No.	Items	Yes	No	If your answer is "No". Please state your reason
1	I like to use Excel worksheets during my learning process			
2	I don't have difficulty in using the Excel worksheets			
3	I become more hard working and put in more effort after using the computer during my chemistry lessons			
4	Using Excel worksheets can save a lot of time in solving chemistry problems			
5	It is easier to evaluate interactive graphs using the Excel worksheets			
6	Through Excel worksheets, charts can be presented accurately in a short time			
7	It is more convenient and easier to plot graph of concentration over time using the Excel worksheets			
8	I feel very interested and enjoy my chemistry lessons with the Excel worksheets			
9	I remember lessons better after using the Excel worksheets			
10	MS Excel worksheets has many advantages which can help in the teaching and learning process of chemistry			
11	The use of Excel worksheets should be encouraged to a wider area of chemistry			

12	Using Excel worksheets in the teaching and learning can encourage discussion among the students and with the teacher			
13	I think Excel worksheets is not suitable to use in chemistry learning			
14	The language and menu in Excel worksheets is easy to understand and user friendly			
15	I have no experience in MS Excel. I am afraid to use it in learning chemistry			

Appendix B

Evaluation Form For Teaching Kinetic Chemistry Using MS Excel Program [**Teacher**]

Part A: Personal Background

- 1 Gender:
- 2 Race:
- 3 Option:
- 4 Name of school/institute:
- 5 Experience of teaching chemistry :

Part B

No.	Item	Yes	No	If "No", state your reason
1	Student use the worksheets actively.			
2	Excel worksheets is attractive.			
3	Excel worksheets motivates students towards the lesson.			
4	Learning through Excel worksheets stimulate student to think.			
5	Learning through Excel worksheets encourages collaborative discussion among students and also between teacher and students.			
6	These worksheets can be used as reference for revision.			

7	Content of worksheets fulfil the objective of lesson.			
8	Language used in Excel worksheets easy to understand.			
9	Facts presented with interactive feature can deliver the lesson effectively.			
10	Other comment on this program: (Please state below)			