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PROMOTING CHEMISTRY MODELLING SKILLS USING GUIDED INQUIRY: MODULE DEVELOPMENT AND VALIDATION

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Abstract

Guided inquiry is one of inquiry learning approaches proposed for teaching chemistry in Malaysia as it is proven to be successful in increasing students thinking skills. However, to further maximize the effectiveness of guided inquiry in increasing students' higher order thinking skills especially modelling skills in chemistry learning, some modification is needed. This article will addresses the development of guided inquiry module that specifically designed for chemistry modelling skills based on 5E phase in inquiry learning. It is consist of five phases including Engagement, Exploration, Explanation, Elaboration and Evaluation integrated with modelling sub skills. The developed module then was verified by four chemistry subject content experts. The results showed that the developed module were suitable for implementation, based on 5E phase. The results also indicated that the developed module met the requirement of the criteria and suitable to be used in chemistry teaching and learning.

Keywords: *Modelling Skills, Higher Order Thinking Skills, Guided Inquiry*

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Introduction

Modelling skills is one of higher order thinking skills (HOTS) in chemistry learning (Kaberman & Dori, 2009; Dori & Kaberman, 2012). Modelling skills involve understanding on structure of molecule and the ability to transfer between molecular representations and the level of chemical representations (Dori & Kaberman, 2012). It is also refer to the skills to explain, interpret and predict phenomena based on the description of the structure and properties in submicroscopic aspect (El Hassane et al., 2012). In chemistry learning, students' modelling skills is enhanced using virtual model (Kaberman & Dori, 2009; Dori & Kaberman, 2012) and real model (Mendoca & Justi, 2011). The use of real model, such as the dough that is formed into balls represent chlorin and natrium ions is successful in encouraging students to generate idea and increasing students' understanding in learning ionic bond (Mendoca & Justi, 2011).

Similarly, virtual model also gives positive results. Virtual model especially computerized molecular modelling was successfully in increasing modelling skills among students (Kaberman & Dori, 2009; Dori & Kaberman, 2012). The study also show the ability of students to draw a complete model of molecule and understanding in level of chemical representations also increase through the usage of virtual model. Currently, the use of model in order to enhance modelling skills in chemistry education has been given a significant amount of attention especially using virtual model (Liu, 2006; Waight & Gillmeister, 2014). However, studies show that using model in terms of visual representation is not very effective (Chang et al., 2010; Adadan, 2013). The complexity of the visual of the model induced confusion and become difficult to interpret (Adadan, 2013).

Therefore, the use of model within pedagogy is suggested (Johnson & Papageorgiou, 2010; Adadan, 2013). Implementation of pedagogy that involving group learning, group discussion, reflection is require in order to help students mastering chemistry modelling skills (Chandrasegaran et al., 2008; Adadan et al., 2009). In chemistry, inquiry learning is widely practiced as pedagogy for teaching and learning (Bunterm et al., 2014). Similarly, inquiry learning is become one of the learning approaches suggested to be implemented in chemistry education in Malaysia (Curriculum Development Centre, 2012). However, inquiry learning was widely practiced using structured inquiry. Limited involvement from the students is currently the main weakness of structured inquiry. This has a very minimal effect toward increasing HOTS (Zion & Mendelovici, 2012).

Differ from structured inquiry, guided inquiry is more effective in increasing thinking skills and HOTS (Sadeh & Zion, 2012; Zion & Mendelovici, 2012). However, to maximise the effectiveness of guided inquiry in increasing students' higher order thinking skills especially in modelling skills, some modification is needed. Hence, this study will discuss the development and validation of guided inquiry module for chemistry modelling skills (GICMM), specifically designed for implementation of chemistry modelling skills in the context of Malaysia.

Methodology

GICMM Development

GICMM was developed and design based BSCS 5E Instrcutional Model (Bybee et al., 2006) as shown in Table 1 below.

Table 1: BSCS 5E Instructional Model (Bybee et al., 2006)

Phase	Explanation
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Based on Table 1, there are five phases in 5E model, Engagement, Exploration, Explanation, Elaboration and Evaluation. At the Engagement Phase, student will use their prior knowledge in order to learn the new knowledge. Next, at the Exploration Phase, students are guided through activities that lead them to conceptual changed. For Explanation Phase, concept, process and skills will be introduced facilitated by teacher explanation. At the Elaboration phase, students will challenged by doing additional activities to gain new experiences. Lastly, at Evaluation Phase, students will assess their understanding towards their learning.

Basically, the main activities in GICMM were design according to guided inquiry 5E phase. However, to ensure GICMM achieve it purpose to increase modelling skills in chemistry, integration between modelling skills and guided inquiry 5E phase using additional activities is needed. Table 2 shows the construct of modelling skills hierarchy that was modified from Dori & Kaberman (2012) used in GICMM.

Table 2: Modelling hierarchy modify from Dori & Kaberman (2012)

Hierarchy	Modelling skills
1	Transfer from molecular to structural formula
2	Transfer from model to molecular formula
3	Transfer from simple molecules to model drawing
4	Understanding at chemical representations level and transfer between the level
5	Transfer from symbol to process level

Based on Table 2, there are five levels of modelling subskills beginning from transfer from molecular to structural formula, transfer from model to molecular formula, transfer from simple molecules to model drawing, transfer between chemical representations and transfer from symbol to process level. However, considering the limitation of student background of knowledge and restriction to the Malaysia chemistry syllabus, GICMM integrate only 3 level of modelling hierarchy; hierarchy 1, 3 and 4. Whereas, hierarchy 2 and 5 is the limitation of this study as, the researchers found that the use of model and the complexity of the structure are not suitable with Malaysia curriculum.

Table 3 shows additonal activities as the results of integration between modelling skills and guided inquiry 5E phase used in GICMM.

Table 3: Additional activities in GICMM

Guided inquiry module for chemistry modelling skills (GICMM)	
Phase	Additional activities
Engagement	• Modelling skills (Hierarchy Level 4) - Transfer between chemical representations (macroscopic and microscopic) - The use of animation that demonstrate the chemical experiment to help student make an observation before and after reaction. (macroscopic) - The use a microscopic diagram to help students to interpret the observation and relate to microscopic level. (microscopic) - Creating hypothesis for both macroscopic and microscopic level. (macroscopic and microscopic)
Exploration	• Modelling skills (Hierarchy Level 4) - Understanding at chemical representations level and transfer between the level (macroscopic, microscopic and symbolic)

	- Creating hypothesis for both macroscopic and microscopic level. (macroscopic and microscopic) - Observation using table involving two aspects before and after reaction to helps students aware about the changes occur in the experiment. (macroscopic) - Students have to complete the table of observation that consists of macroscopic, microscopic and symbolic. (macroscopic, microscopic and symbolic) - The use of microscopic diagram in lab report (microscopic)
Explanation	• Modelling skills (Hierarchy Level 1) – Transfer from molecular to structural formula - Concepts is introduce using hypothetical questions involving chemical and structural formula • Modelling skills (Hierarchy Level 3) – Transfer from simple molecules to model drawing - Build up clay model of chemical structure - Model drawing • Modelling skills (Hierarchy Level 4) - Understanding at chemical representations (microscopic)
Elaboration	• Modelling skills (Hierarchy Level 4) - Transfer between chemical representations (macroscopic, microscopic and symbolic) - The use question in the form of chemical diagram (experiment) to clarify the concept from chemical representations
Evaluation	• Modelling skills (Hierarchy Level 4) - Understanding at chemical representations (microscopic) - The use of microscopic diagram in self-reflection

Based on Table 3, the main aspect of modelling skills that was embedded in GICMM is the fourth hierarchy of modelling subskills; understanding at chemical representations level and transfer between the level of chemical representations. This becomes a main concern because understanding and transferring between all levels of chemical representations is the major problem in learning chemistry (Chandrasegaran et al., 2008; Sirhan, 2007; Jaber & Boujade, 2012). Other than that, GICMM also emphasized on chemical and structural formula, manipulating model as well as model drawing.

GICMM Validation

Validation of GICMM was done to ensure GICMM is suitable to be used for teaching chemistry in Malaysia schools. Four chemistry subject content experts were selected to verify that GICMM fulfilling the requirement of content and linguistic validity. In terms of content validity, experts were referred to verify that the developed GICMM is suitable with three aspects of content validity; suitability with guided inquiry 5E phase including of Engagement, Exploration, Explanation, Elaboration and Evaluation, suitability with construct of modelling skills and suitability with Malaysia form four chemistry curriculum specifications.

In terms of linguistic validity, experts were referred to verify that GICMM used suitable language and terms especially in aspect of chemistry terms. The validity of GICMM involving four chemistry content experts, however the experts verify the different aspects according to their expertise as summarize in Table 4.

Table 4: Distribution of content experts according to validity aspect

Validity		Content Experts	No. of content experts
Content validity	Suitability with guided inquiry 5E phase	1, 3, 4	3
	Suitability with construct of modelling skills	2, 3, 4	3
	Suitability with chemistry specifications	3, 4	2
	Linguistic validity	1, 2, 3, 4	4

Result and Discussion

Table 5 shows experts' input regarding the validity of GICMM according to guided inquiry 5E phase criteria.

Table 5: Results of GICMM suitability with guided inquiry 5E phase criteria

No	Description	Percentage given by experts (n=3) (%)										Mean
		Lowest ⟷ Highest										
		1		2		3		4		5		
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
1	Concepts / skills in the module is in line with the curriculum		-		-		-	2	66.7	1	33.3	4.33
2	Learning objectives are clear , appropriate , measurable		-		-		-	2	66.7	1	33.3	4.33
3	Substances listed are complete and appropriate		-		-		-	2	66.7	1	33.3	4.33
4	Activities in the orientation phase : Increase students interest		-		-		-	1	33.3	2	66.7	4.67
5	Encourage students to create a hypothesis		-		-		-	2	66.7	1	33.3	4.33

6	Provide opportunities for students to use existing knowledge	-	-	-	2	66.7	1	33.3	4.33
7	Direct and continuous with the exploration phase	-	-	-	2	66.7	1	33.3	4.33
8	During the exploration phase, Students do assignments actively	-	-	-	2	66.7	1	33.3	4.33
9	Provide opportunities for students to develop the inquiry skills	-	-	-	2	66.7	1	33.3	4.33
10	Activity in exploration phase, Student-centered	-	-	-	2	66.7	1	33.3	4.33
11	Involving hands-on and minds-on activity	-	-	-	1	33.3	2	66.7	4.67
12	Inquiry activities in the exploration phase evaluated using formative evaluation to prove that learning is occur	-	-	-	2	66.7	1	33.3	4.33
13	During the concept development phase, Activities are continuous from exploration phase	-	-	-	1	33.3	2	66.7	4.67
14	Various of questions used (convergent and divergent)	-	-	-	1	33.3	2	66.7	4.67
15	Question used (related to activity) leads to the development of concepts and skills	-	-	-	1	33.3	2	66.7	4.67
16	Contains of complete explanation of concepts, terms or skills learned	-	-	1	33.3	1	33.3	1	33.3	4.00

17	Allowing students to use a variety of approaches to explaining and illustrates the concept or skill	-	-	-	2	66.7	1	33.3	4.33
18	Encourage students to create continuity between life and concept or skill that built	-	-	-	3	100		-	4.00
19	During Application Phase Activities are continuously from exploration phase	-	-	-	2	66.7	1	33.3	4.33
20	Provide opportunities for students to apply concepts or skills that are built into the new situation	-	-	-	2	66.7	1	33.3	4.33
21	During the closing phase Activities discussions allow students to evaluate current understanding about a concept or skill through appropriate formative assessment	-	-	-	2	66.7	1	33.3	4.33
22	Contains assessment / reflection in various forms and approaches	-	-	-	2	66.7	1	33.3	4.33
23	Evaluation / reflection is consistent with the learning objectives	-	-	-	2	66.7	1	33.3	4.33
24	Evaluation / reflection is clear, appropriate and measurable	-	-	-	1	33.3	2	66.7	4.67
								Average Mean	4.40

Based on Table 5, all the experts agree that GICMM is fulfilled the criteria of guided inquiry 5E phase. However, explanation and terms used in GICMM has to be corrected. Overall, GICMM is suitable to be use to implement modelling skills in chemistry based on average mean value of 4.40.

Meanwhile, Table 6 shows the experts view regarding validity of GICMM with construct of modelling skills criteria.

Table 6: Results of GICMM suitability with construct of modelling skills criteria

No	Description	Percentage given by experts (n=3) (%)										Mean
		Lowest ◄								► Highest		
		1		2		3		4		5		
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
1	The use of the chemical representation level in the learning phase is appropriate		-		-		-	1	33.3	2	66.7	4.67
2	The use diagrams particles in the learning phase is appropriate		-		-		-	2	66.7	1	33.3	4.33
3	Application of modelling skills in the learning phase is appropriate		-		-		-	2	66.7	1	33.3	4.33
4	The arrangement of the modelling skills hierarchy in the learning phase is appropriate		-		-		-	1	33.3	2	66.7	4.67
5	Model building activity in the learning phase is appropriate		-		-		-	2	66.7	1	33.3	4.33
6	Integration of modelling skills in the guided inquiry learning is appropriate		-		-		-	2	66.7	1	33.3	4.33
									Average Mean			4.44

Based on Table 6, GICMM got the positive comment from all the experts and average mean value was 4.44. All the experts agree that GICMM contains modelling skills criteria and it shows that GICMM is suitable to be used to implementing modelling skills.

In addition, all the experts agree that GICMM is fulfilled the form four chemistry specifications as shown in Table 7. Based on Table 7, it can be conclude that GICMM is suitable to be used to implementing modelling skills in Malaysia chemistry classroom.

Table 7: Results of GICMM suitability with chemistry curriculum specifications

Description	Percentage Given by Experts (n=2) (%)	
	Yes	No
The contents of the instrument (GICMM) that has been developed is suitable to be used by students and has fulfilled the requirements of the form four chemistry syllabus	100	-

In term of linguistic validity, Table 8 shows the feedbacks from the experts regarding language and term used in GICMM.

Table 8: Results of linguistic validity

No	Description	Percentage given by experts (n=4) (%)										Mean
		Lowest ◄								► Highest		
		1		2		3		4		5		
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	
1	The page layout is interesting	-		-		-		3	75	1	25	4.25
2	The size of the fonts are suitable and easy to read	-		-		-		2	50	2	50	4.50
3	The size of the diagrams used are suitable with the content	-		-		-		3	75	1	25	4.25
4	The diagrams used are suitable with the content	-		-		-		2	50	2	50	4.50
5	The diagrams are easy to read	-		-		-		2	50	2	50	4.50
6	Tables used are well-organized	-		-		-		4	100	-		4.00
7	The tables used are well arranged and easy to be understood	-		-		-		3	75	1	25	4.25
8	The texts of the contents are well arranged and easy to be understood	-		-		-		3	75	1	25	4.25
9	The instructions given in sentence are clear and step by step	-		-		-		3	75	1	25	4.25
10	The instructions given	-		-		-		4	100	-		4.00

	are clear									
11	The language used is easy to be understood	-	-	1	25	2	50	1	25	4.00
12	There are no spelling errors	-	-		-	3	75	1	25	4.25
13	The illustrations are suitable with the age of students	-	-	1	25	2	50	1	25	4.00
14	The illustrations are suitable with the level of students learning	-	-		-	3	75	1	25	4.25
								Average Mean		4.23

Based on Table 8, all the experts agree that GICMM is valid in term of linguistics. However, some language and terms used in GICMM has to be corrected. Furthermore, some illustrations used also need to be improves. Overall, based on average mean value of 4.23 and positive response from the experts, GICMM is suitable to be use to implementing modelling skills in chemistry.

Conclusion

This paper discusses the development and validation of developed GICMM for the purposes of implementing modelling skills in Malaysia chemistry classroom. The finding shows that certain aspects in this module need to be improved. Based on the positive results, GICMM is suitable to be used for chemistry teaching and learning in Malaysia.

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