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Validating The Usability Of Organic Reaction Teaching Model (Ortm): The Experts' Collective Opinions

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ABSTRACT

There are many procedures to be followed in the validation of teaching models. One of the validation approaches is to find the opinions of the community of experts on the suitability of the model components, and the overall usability using the modified Fuzzy Delphi Technique (FDT). Compared with other sectors, such as technology education, business, and health, the use of FDT to validate components of educational frameworks, models, modules, and curricula was still recent in the field of science education. This research, therefore, validated the components of the organic reaction teaching model (ORTM) based on the shared opinion of experts. Fourteen experts were chosen as panels for the evaluation using FDT. The findings indicate that the organic reaction teaching model components are appropriate and have been highly rated by the experts (d= 98.1%, DV≥9.8). The proposed model constructs provide essential planning guides for model implementation and offered alternative validation procedures for model developers in science education.

KEYWORDS: Instructional model, Fuzzy Delphi technique, Experts' collective opinion, Organic reaction mechanisms.

INTRODUCTION

Chemistry is a core subject for science-based courses in the pre-university programmes designed to equip students with basic chemistry knowledge to be prepared for science-related undergraduates programmes in both local and overseas universities (e. g. Academy of Sciences Malaysia, 2015; Afolabi, 2017; Fantke et al., 2019; Fleer, 2019; James & Singer, 2016; Marginson, 2018; Mensah & Jackson, 2018; Veloo, Hong, & Lee, 2015). Chemistry is both a core and prerequisite subject to study science-related programs such as agriculture, genetics, biochemistry, food science, forestry, medicine, and other technology-based courses (Flynn & Amellal, 2015; Talib, Nawawi, Ali, & Mahmud, 2012).

In the Malaysian education system, organic chemistry is made up of 50% of the chemistry curriculum in pre-university colleges that must be learned by students in science- related programs during the second semester of the program (Azraai & Talib, 2015; Azraai, Talib & Ibrahim, 2015). Organic chemistry is concerned with the study of carbon and its compounds in various forms of matter. It includes several of the groups of organic compounds, commonly include hydrocarbons, benzene compounds, and their derivatives, haloalkanes, carbonyl compounds, amines, carboxylic acids, amino acids, and polymer compounds, and the pathways of their reactions. Organic chemistry topics such as functional groups, nucleophiles, electrophiles, synthesis, and reaction mechanisms are of utmost importance in different areas of economic development, like agricultural Science, petrochemicals, textile sciences, and pharmaceutical sciences (Bodé & Flynn, 2016; Cooper, Stowe, Crandell, & Klymkowsky, 2019). To address the spiral nature of the chemistry curriculum, that involved interwoven and re-occurring concepts with considerable complexity of content and relevant across the educational level, the curriculum of the pre-university program was designed to create a connection between general chemistry contents knowledge acquired at the secondary level and the content to be taught at the university level (Azraai & Talib, 2015). Also, to extend and reinforce the expertise of students and prepare to train them for careers in science and technology (Achimugu, 2018 & Donkoh, 2017). Therefore, a conceptual understanding of basic organic chemistry is necessary for learning advanced courses in science-based subjects such as agriculture, biochemistry, molecular biology, food science, and pharmaceutical sciences.

However, at both local and international levels, the challenges faced by students in learning organic reaction mechanisms (ORM) have been of considerable concern to academics (Kaanklao & Suwathanpornkul, 2018; Othman, 2016; Othman Talib, Azraai Othman, & Tengku Putri Norishah, 2014; Sevian & Couture, 2018; Weinrich & Sevian, 2017a). For example, numerous researches have been performed to describe and account of the events taking place during the reaction such as breaking and forming covalent bonds and the use of arrow pushing formalisms to explicitly show the movement of electrons (Caspari, Kranz, & Graulich, 2018; Cooper et al., 2019; Galloway, Leung, & Flynn, 2018; Galloway, Stoyanovich, & Flynn, 2017b, 2017a; Havanki, 2018; Lo & Tang, 2018; Popova & Bretz, 2018a). Other researchers were concerned about the common errors of students in organic reaction mechanism (Berg & Ghosh, 2013; Bodé, Deng, & Flynn, 2019; Caspari, Weinrich, Sevian, & Graulich, 2018; Flynn & Featherstone, 2017) and their results revealed that common errors in ORM by students hindered understanding of many other advanced organic reactions in different science-related courses. Talib, Othman and Putri (2014) therefore claimed that a good understanding of the fundamentals of ORM is necessary for the synthesis of organic compounds and crucial for the study of advanced topics in organic chemistry. Bode and Flynn (2016) also state that the ability of students to solve the fundamental ORM task is the highest cognitive learning outcome of organic chemistry. Meanwhile, because of the lack of an explicit instructional model, inadequate understanding of the basic concepts, and the abstractness of the subject, learning basic ORTM was very difficult for students (Bongers, Northoff, & Flynn, 2019 & Gilbert, 2005). In addition, the widely used instructional model for teaching chemistry was the representation model proposed by Johnstone (1993). The model was based on the notion of interpreting and expressing chemical information based on three levels of representation, historically known as the Johnstone Chemical Triangle. The model labelled chemical concepts as macro, micro, and symbolic levels to explain measurable and observable structures and phenomena in our environment using chemical and mathematical symbols, and their relationship (Gabel, 1999a; Gilbert & Treagust, 2009; Johnstone, 1991 & Talanquer, 2011). This presentation has served as a point of reference for numerous chemical education studies and has streamlined the work of chemistry educators around the world (Cheng & Gilbert, 2017).

Nevertheless, Johnstone model of chemical triangle has undergone series of adoption and adaptation by several scholars and produced different interpretations of chemical triangle. The study of Johnstone's own articles, for instance, reveals that he refers to the components of the chemistry triangle in different ways: the thought levels (Johnstone, 1991), the components or modes(Johnstone, 1993), and the types of subject matter (Johnstone, 2000). Scholars such as Gabel and his colleague, who viewed Johnstone's representation model very closely, have used additional terms such as the levels of teaching (Gabel, 1993), representation level (Gabel, 1999a; Gilbert & Treagust, 2009), the molar, intermolecular and electrical properties of the chemical phenomenon (Jensen, 1998) and the intermolecular level (Ladhams, 2004). More so, the view of Gilbert and Treagust (2009) clarified the chemical triangle as the level of representation has been prevalent in recent years, chemist continues to raise questions about the macro level of observable and concrete stuff called "representation." On this basis, if we are to obtain a clearer understanding, more debate is needed.

In the preparation of chemistry instruction, much of this modification of the initial chemical triangle required chemistry teachers to think more critically about alternative models, particularly in organic chemistry teaching. In addition, this reinterpretation caused a great deal of uncertainty and ambiguity that makes students memorized by rote and fails to find a response when a task is given to them without demonstrating the steps involved in the task (Talanquer, 2011). Similarly, basic concepts were taught because they appeared first in the syllabus as independent topics with no connections to be integrated and transformed in the learning of the related concepts (Talanquer, 2015).

Students' Common Errors in ORM

Making errors is part of human life and behaviour, students commit errors and try several steps in every step of learning. An error is described as "actions or choices that should have been avoided that could lead to real or possible negative effects (Tulis, Steuer, & Dresel, 2016)." For instance, errors in the organizational context include the wrong doctor's prescription, the student's wrong answer, and incorrect software programming coding. In all these cases, errors have adverse effects that adversely impact consumers, clients, patients, students, and organizations that may have been prevented if the actions were correctly conducted. In chemistry education teaching and learning process, errors are made by students such as drawing five bonds to carbon atoms, wrong use of arrows in organic reaction mechanisms have been widely reported by researchers (Andrés, Berski, & Silvi, 2016; Flynn & Featherstone, 2017; Grossman, 2003; Weinrich & Sevian, 2017) which need to be studied. For example, chemistry teachers have been warned of common dangers and myths that harass students (Grossman, 2003). He advised that teachers pay attention to common mistakes, as the inability to observe and monitor their consequences has led many test points to be missed over the years. Students make some of the most common mistakes in drawing organic reaction mechanisms: incorrect arrow orientation and direction, arrow shortage, hypervalent carbon formation, mixed media errors, and inability to conserve charges (Cruz-Ramirez De Arellano & Towns, 2014; Popova & Bretz, 2018b; Weinrich & Sevian, 2017a). Likewise, analysis of an introductory organic chemistry students' activity directed to use arrow pushing to solve organic reaction mechanisms task revealed that students predicted the final product, the mechanisms are most likely from memorization and adorned with arrows that are not in line with the position of the atom and electron pair in the reaction mechanisms (Grove & Lowery Bretz, 2012).

An earlier study by Santagata (2005) revealed that the way teachers manage students' errors has been locally embedded and varies between countries. For example, students in the United States and China produced the same types and number of mathematical errors but the responses teachers differ significantly between countries (Schleppenbach, Flevares, Sims, & Perry, 2007). Teachers in the United States followed errors with comments or instant corrections, while Chinese teachers requested follow-up questions to facilitate students' discussion. Hiebert, Stigler, and Manaster (1999) stated in another study that Japanese teachers treat the errors of their students by stressing the good side of errors and promoting discussion of the misconceptions of students. This demonstrates that the variations in the error control methods of teachers depend on how the instructor interpreted the errors. Although the body of empirical research has documented differences in the way mathematics teachers deal with the errors of students between teachers in different countries, less research focuses on disparities between methods of chemistry teachers to deal with the errors of students, notably in mechanisms of organic reaction. Theories and models on classroom target systems have demonstrated that real classroom activities impact the perceptions and values of students (Carole, 1992). It is concluded, along with this theoretical context, that the error prevention techniques of teachers in the classroom have a significant influence on the prevention and correction of errors of students.

Model Validation

Models are simple explanations that provide idealized structure and order for complex real-life scenarios that are unpredictable on the surface (Gilbert, Boulter, & Elmer, 2000). Instructional models are philosophical representations of reality constructed by scholars to make sense of the ideas for conceptual understanding of the phenomenon (Akaygun, 2016). Models are usually constructed through phases including the need analysis, development, and validation to justify the need, identify the constructs, and evaluate the usability of the model, respectively. Model validation is used to obtain and evaluate scientific evidence in a deliberately structured manner to explain the usability of the model in the field or to justify the usefulness of the various components of the model (Richey & Klein, 2005). This is an approach that involves the degree to which the inferences are appropriate and substantive, as with the use of the word validity surrounding interpretation and study design. Yet, Andrews and Goodson (1980) noted that "the fidelity of the model to the actual processes it represents will decrease as the specificity of the model decreases" (p. 3). In some instances, the use of a model needs substantial clarity and amplification to provide the necessary details for its implementations. Validation of the model creates strong concept criteria, frequently used as communication mechanisms to envision, and clarify the planned strategy and play a part in the development of ideas and their incorporation into reality.

There are two important categories of models, both of which are candidates for validation. The first defines and reveals the interrelationships between the factors influencing the design process, and the second suggested steps to be taken in the design process (Kosucu, 2017). These two configurations as conceptual and procedural models (Tracey& Richey, 2007). Procedural models are beginning with various modes of analysis and proceeding through the designing of a series of specifications for the learning environment and the development of learning materials (Gustafson & Branch, 2002). Thus, the validation processes encompass the whole process, while the model's implementation is ongoing. Some procedural models are visual and sequential-type diagrams. Models developed by Dick, Carey, and Carey (2001), and Ragan, Smith, and Curda (2008) are typical examples of procedural models related to comprehensive design projects. In the development process, several differences are mostly expressed by more basic models designed to appeal to the peculiarities of individual student classes, school curriculum, modes of distribution methods, unique phenomena, or even specific design ideologies. in procedural models, more specific aspects of the design, development, and validation processes were discussed. For example, the implementation model of English language communication skills for undergraduates in the mobile learning program (Abdullahi, 2014), the higher-order thinking teaching model for basic education students (Ahmed and Artosh (2016) and skives, the engineering education program training curriculum model (Ridhuan, 2016).

Theorists and models developers are apt to presume the validity of a model if it is a logically and coherently supported by literature (Dutt, Tan, Alagumalai, & Nair, 2019). Both are often guided by the realistic consequences of their use and the happiness of the users. In this article, model validation is seen as a carefully designed method of gathering and evaluating empirical evidence to demonstrate the usefulness of a model built to help the different constructs and instructional activities of the model itself namely the Organic Reaction Teaching Model (ORTM). The ORTM developed consisted of 30 teaching activities clustered into five constructs of language symbolism, mechanistic reasoning, visual representation, crosscutting concepts, and reflection grouped into three domains of error treatment namely error avoidance, error interference and error correction domains.

Research Objective

This study aimed at validating these ORTM components based on experts' collective opinion. Thus, this paper, therefore, aims to respond to the following research questions:

RQ1: What are the experts’ opinions on the suitability of the instructional activities proposed in the ORTM?

RQ2: What are the experts’ opinions on the classification of instructional activities into the five respective constructs as proposed in the ORTM?

RQ3: What are the experts’ opinions on the overall suitability of the ORTM?

Research Methodology

Expert questionnaires are valuable method for data collection in a Delphi survey where face to face interviews of individuals is not practical in terms of time and group arrangement (Dalkey & Helmer, 1963). The items of the questionnaire were drawn from past related literature and validated by experts in an open format. The study included a total of 14 experts. Participants in this research were chemistry and science education experts who are also lecturers at the Universities and Matriculation Colleges offering pre-university programmes in Malaysia. The experts were expected to express their views on different issues that are useful for enhancing the course material. This article reported on the experts’ validation of the constructs of the organic reaction teaching model. The researchers chose 14 experts based on the views of Adler and Ziglio (1996), who claimed that 10 to 15 participants were enough in the Delphi technique. According to Jones and Twiss (1978), this number of participants is sufficient to achieve a consensus of experts. The validation is based on considering the experts' agreement on three dimensions of the model constructs. In the first place, for an item to be accepted, the threshold value, d, must be ≤ 0.2, (Abdullah & Siraj, 2018; Ching-Hsue & Yin, 2002). The threshold value, ‘d’ is calculated to determine the collective opinion of the experts for each item of the questionnaire using the formula

$$d(M, m) = \sqrt{\underline{1}}\,[(M1 - m_1)^2 + (M2 - m_2)^2 + (M3 - m_3)^2]$$

The threshold values for each item were presented in Table 1. Thus, in this study items with threshold values that exceeded 0.2 were presented in bold, they were the items that did not achieve experts’ consensus. For instance, the opinions of expert’s number 9 and 10 were not in agreement with other experts on item 2.5 of the questionnaire.

Table 1 - Threshold Value, d, for the ORTM Validation Questionnaire Items

1	0.033	0.295	0.092	0.055	0.216	0.011	0.147	0.211	0.081	0.245	0.174	0.125	0.109	0.090	0.018	0.207	**0.253**	0.223	0.011	0.023	0.120	0.044
2	0.033	0.098	0.061	0.098	0.080	0.147	0.011	0.211	0.171	0.152	0.027	0.125	0.109	0.162	0.018	0.189	0.147	0.223	0.147	0.130	0.120	0.044
3	0.033	0.098	0.061	0.055	0.080	0.011	0.011	0.078	0.081	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.044
4	0.033	0.059	0.092	0.055	0.080	0.011	0.011	0.078	0.081	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.169	0.011	0.023	0.033	0.044
5	0.033	0.098	0.092	0.098	0.080	0.011	0.011	0.181	0.081	0.018	0.225	0.029	0.044	0.162	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.109
6	0.033	0.098	0.061	0.055	0.080	0.011	0.011	0.078	0.081	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.044
7	0.033	0.059	**0.302**	0.055	0.080	0.011	0.011	0.078	0.081	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.044
8	0.033	0.059	0.061	0.098	0.080	0.011	0.011	0.181	0.081	0.018	0.225	0.029	0.044	0.090	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.044
9	0.033	0.098	0.092	0.055	**0.472**	0.011	0.011	0.181	0.171	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.463	0.011	0.023	0.033	0.09
10	0.033	0.059	0.092	0.098	**0.472**	0.011	0.011	0.181	0.171	0.018	0.027	0.029	0.044	0.090	0.018	0.063	0.011	0.463	0.011	0.023	0.033	0.044
11	0.120	0.098	0.092	0.055	0.080	0.011	0.011	0.078	0.081	0.018	0.027	0.272	0.044	0.090	0.018	0.063	0.011	0.089	0.011	0.023	0.033	0.044
12	0.120	0.098	0.061	0.055	0.176	0.253	0.253	**0.475**	0.171	**0.245**	0.027	0.029	0.044	0.162	0.234	0.189	0.011	0.169	0.253	0.023	0.033	0.044
13	0.120	0.295	0.092	0.098	0.216	0.011	0.147	0.211	0.224	0.152	0.027	0.125	0.109	0.162	0.018	0.189	0.011	0.089	0.011	0.023	0.033	0.109
14	0.033	0.098	0.061	0.055	0.080	0.147	0.011	0.211	0.171	0.152	0.027	0.125	0.109	0.162	0.018	0.189	0.147	0.223	0.147	0.130	0.120	0.109

* d≤0.2.

Secondly, the threshold value must exceed the 75% agreement level of the experts. However, Ching-Hsue and Yin (2002) proposed that for the validation of the entire model components, and the overall threshold value for all the questionnaire items was calculated using the relation:

d =

Thus, to determine the appropriateness of the ORMT model components and the overall usability, threshold value for all the questionnaire items were calculated as follows:

d = $Total\ Experts^F Re$

= 98.1%

Thirdly, items with defuzzification values that indicated experts' opinions from moderately to strongly agree were considered appropriate (Abdullahi, 2014). A seven-point linguistic scale was translated into the responses of the participants of the validity survey questionnaire items. For example, in the Likert scale, an item rated as strongly accepted has a value of seven (7) which is translated to three linguistic values of 0.9, 1, & 1, meaning minimum (m1), optimum (m2), and maximum (m3) values, respectively. The defuzzification value is calculated using the formula:

1

$(m1 + m2 + m3)$
$\times 14$

Where 14 is the total number of experts that participated in the validation of the model usability. For example, an item rated as strongly agreed would have a defuzzification value of:

$$DV = {}^{1} \times (0.9 + 1 + 1) \times 14$$

= 13.5

Table 2 indicated the Likert scale ranging from strongly agree (7), Agree (6), moderately agree (5), slightly agree (4), disagree (3), slightly disagree (2), and strongly disagree (1) into the linguistic scale and the corresponding defuzzification values for each response.

Table 2 Determination of Defuzzification Value

Responses	Likert Scale	Linguistic scale	Defuzzification Value
Strongly Agree	7	0.9, 1, 1	13.5
Agree	6	0.7, 0.9, 1	12.1
Moderately Agree	5	0.5, 0.7, 0.9	9.8
Slightly Agree	4	0.3, 0.5, 0.7	7.0
Disagree	3	0.1, 0.3, 0.5	4.2
Slightly Disagree	2	0.0, 0.1, 0.3	0.9
Strongly Disagree	1	0.0, 0.0, 0.1	0.5

Findings and Discussion

The overall threshold value (d) calculated was 98.1%. This indicates that the threshold value has exceeded the 75 percent consensus level, meaning that participants have achieved the required consensus in their opinions on all the items in the ORTM usability survey questionnaire. A second round of the Fuzzy Delphi survey is therefore not expected because the threshold value met the experts' 75 percent agreement level. The next step was to evaluate the collective opinion of the experts on the usability of the model as follows:

RQ1: What are the opinions of the experts on the suitability of the instructional activities suggested in the ORMT model?

Research question RQ1 was answered by analyzing the responses of the experts on the following item of the questionnaire "1.1: Do you agree with the instructional activities suggested in the ORMT model?" shown in Table 3

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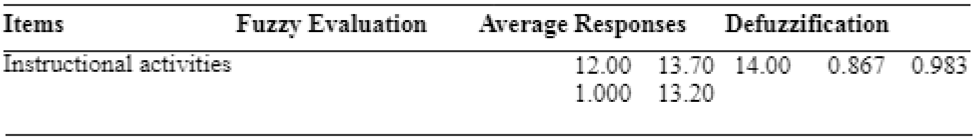
Table 1 Experts' Collective Opinion on Instructional activities



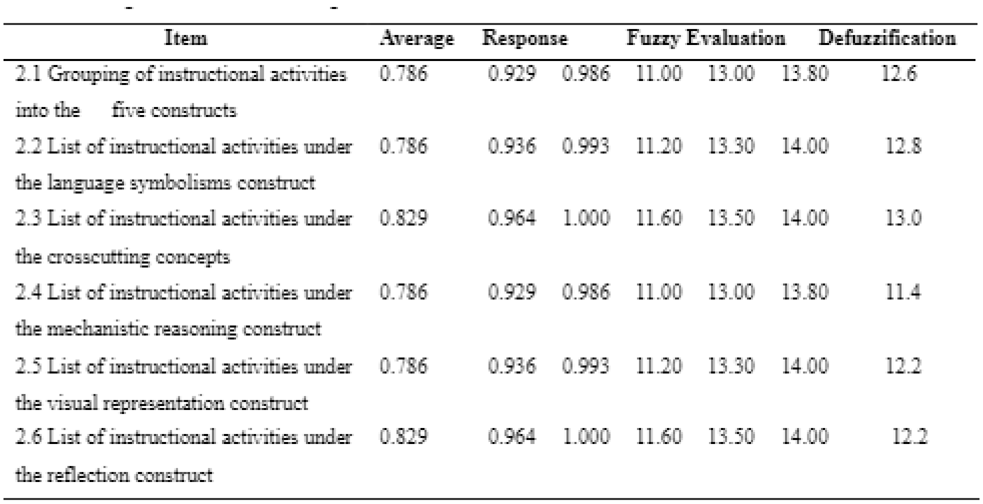
Items	Fuzzy Evaluation	Average Responses	Defuzzification
Instructional activities	12.00 13.70 14.00	0.867 0.983 1.000	13.20

A defuzzification value of 13.2 which is between the moderately agreed value of 9.8 and consensually strongly agreed value of 13.5 was recorded (see Table 3). This has demonstrated that all experts have agreed to this questionnaire item.

RQ2: What are the experts' opinions on the classification of instructional activities into the five respective constructs as proposed in the model?

This section was aimed at determining whether the experts agreed with the classification of the instructional activities of the ORTM under the five constructs. Hence, RQ2 was answered by analysing the experts' collective opinion of the questionnaire items shown in Table4 4.

Table 2 Experts' Collective Opinion on Classification of the Model Construct



Item	Average	Response		Fuzzy Evaluation			Defuzzification
2.1 Grouping of instructional activities into the five constructs	0.786	0.929	0.986	11.00	13.00	13.80	12.6
2.2 List of instructional activities under the language symbolisms construct	0.786	0.936	0.993	11.20	13.30	14.00	12.8
2.3 List of instructional activities under the crosscutting concepts	0.829	0.964	1.000	11.60	13.50	14.00	13.0
2.4 List of instructional activities under the mechanistic reasoning construct	0.786	0.929	0.986	11.00	13.00	13.80	11.4
2.5 List of instructional activities under the visual representation construct	0.786	0.936	0.993	11.20	13.30	14.00	12.2
2.6 List of instructional activities under the reflection construct	0.829	0.964	1.000	11.60	13.50	14.00	12.2

A consensus between the experts on the grouping of the ORTM's instructional activities into the five respective constructs (item 2.1) with a defuzzification value of 12.5 and on all the lists of activities under each construct was shown in Table 4. In the list of constructs, the highest consensus of experts with a defuzzification value of 13.0 was attained by the mechanistic reasoning construct (item 2.3) while the visual representation construct (item 2.4) reached the lowest count (defuzzification value = 11.4). Experts agree strongly on mechanistic reasoning by consensus (item 2.3, d>12.1) and agree on visual representation by consensus (item 2.4, d>9.8). Similarly, the consensus between the experts on the construct of language symbolisms (item 2.2, d= 12.8), cross-cutting constructs (item 2.3, d= 13.0), and the construct of reflection (item 2.6, d= 12.2) agreed strongly with the appropriate defuzzification values above 12.1 (see Table 2) within the range of consensual agreement. Thus, conclusively, the experts' collective opinion was from consensually agreed to strongly agree with the classification of the instructional activities in the ORTM according to the five constructs as language symbolisms, crosscutting concepts, mechanistic reasoning, visual representation, and reflection activities. RQ3: What are the experts' opinions on the overall suitability of the ORTM?

To determine the overall suitability of the model elements (instructional activities and constructs), the collective opinion of the experts on the suitability of the ORTM in the teaching and learning to help students meet their learning outcomes and their ability to transcend the common errors of students was collected using items 3.1 to 3.12 of the questionnaire. To validate the overall suitability of the ORTM, as shown in Table 5, the collective opinion of the experts on the products was evaluated.

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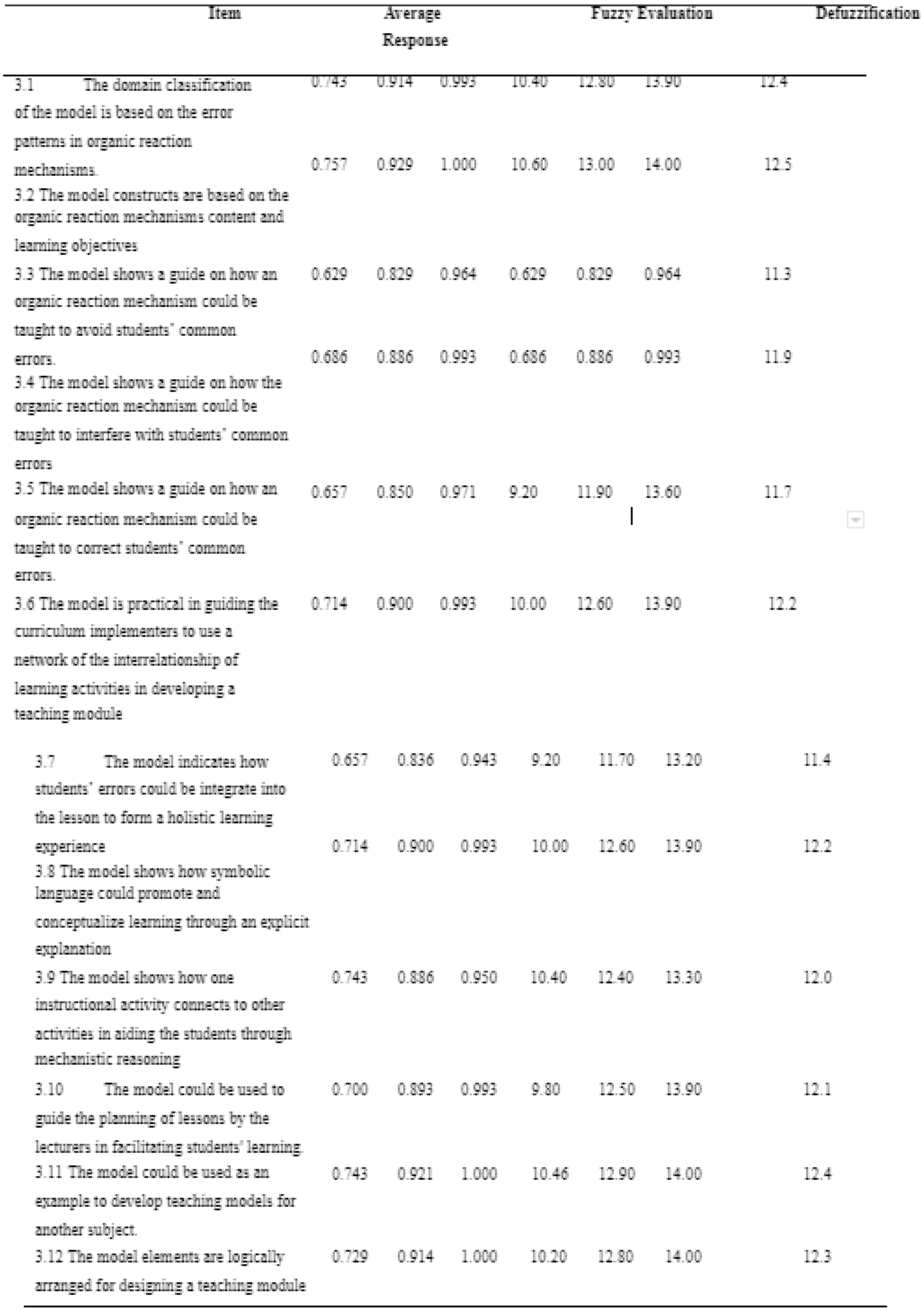
Table 3: Experts' Collective Opinion on the Suitability of the Model in Teaching ORM



Item	Average Response			Fuzzy Evaluation			Defuzzification
3.1 The domain classification of the model is based on the error patterns in organic reaction mechanisms.	0.743	0.914	0.993	10.40	12.80	13.90	12.4
3.2 The model constructs are based on the organic reaction mechanisms content and learning objectives	0.757	0.929	1.000	10.60	13.00	14.00	12.5
3.3 The model shows a guide on how an organic reaction mechanism could be taught to avoid students' common errors.	0.629	0.829	0.964	0.629	0.829	0.964	11.3
3.4 The model shows a guide on how the organic reaction mechanism could be taught to interfere with students' common errors	0.686	0.886	0.993	0.686	0.886	0.993	11.9
3.5 The model shows a guide on how an organic reaction mechanism could be taught to correct students' common errors.	0.657	0.850	0.971	9.20	11.90	13.60	11.7
3.6 The model is practical in guiding the curriculum implementers to use a network of the interrelationship of learning activities in developing a teaching module	0.714	0.900	0.993	10.00	12.60	13.90	12.2
3.7 The model indicates how students' errors could be integrate into the lesson to form a holistic learning experience	0.657	0.836	0.943	9.20	11.70	13.20	11.4
3.8 The model shows how symbolic language could promote and conceptualize learning through an explicit explanation	0.714	0.900	0.993	10.00	12.60	13.90	12.2
3.9 The model shows how one instructional activity connects to other activities in aiding the students through mechanistic reasoning	0.743	0.886	0.950	10.40	12.40	13.30	12.0
3.10 The model could be used to guide the planning of lessons by the lecturers in facilitating students' learning.	0.700	0.893	0.993	9.80	12.50	13.90	12.1
3.11 The model could be used as an example to develop teaching models for another subject.	0.743	0.921	1.000	10.46	12.90	14.00	12.4
3.12 The model elements are logically arranged for designing a teaching module	0.729	0.914	1.000	10.20	12.80	14.00	12.3

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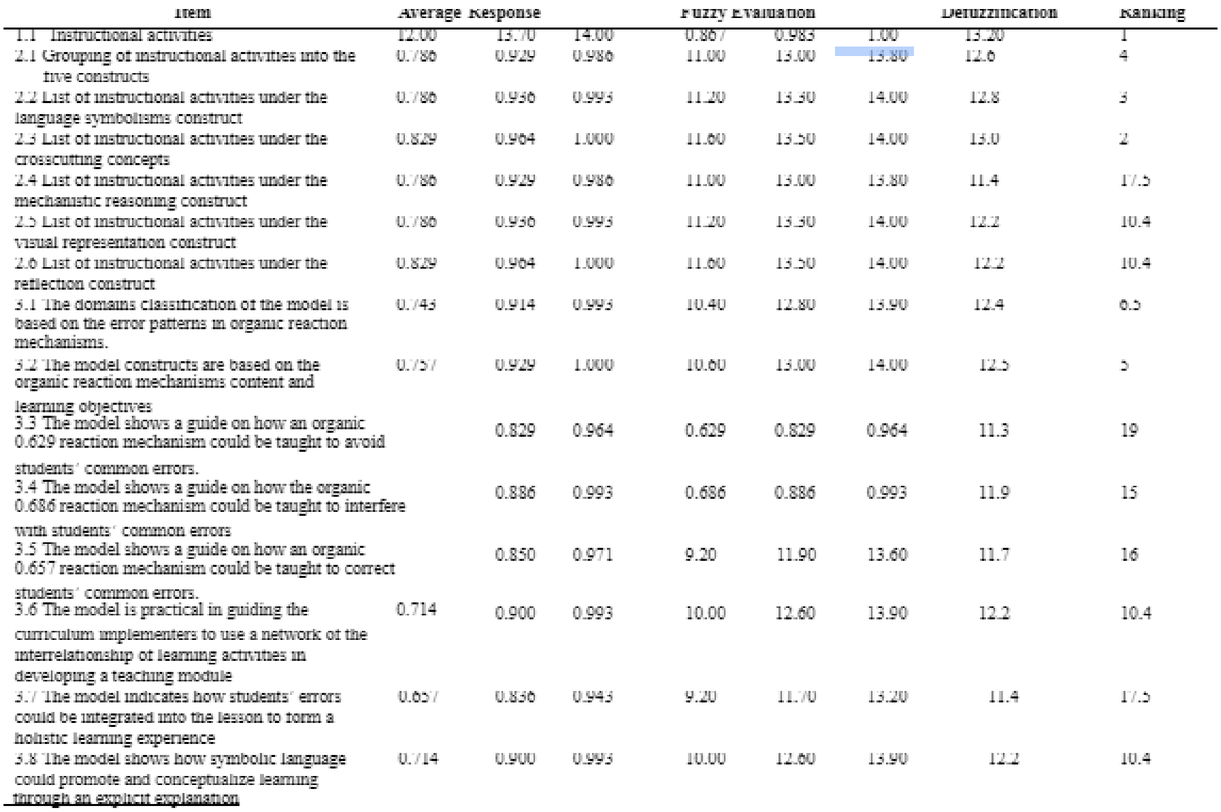
Implying the outcome for item 3.3 in Table 5, the experts decided by consensus with a defuzzification value of 11.3 above the minimum value of 9.8 that the model shows a guide about how to teach the organic reaction mechanism. The total range of agreements for this item was moderately agreed to agree. The same set of agreements is also shared with items 3.4, 3.5, and 3.7 (defuzzification values; 11.9, 11.7 & 11.4, respectively). It indicates the opinion of the experts from moderately agreed to agree on how the model shows a guide on how organic reaction mechanism could be taught to interfere with students' common errors that occur during the class session (Item 3.4); guide on how organic reaction mechanism could be taught to correct students' common errors (item 3.5) and the model indicates how students' errors could be integrated into the lesson to form a holistic learning experience (3.7).

However, for item consensually agreed that the domain classification of the model is based on the patterns of students' common errors in organic reaction mechanisms (Item 3.1). They also agreed that the model constructs are selected based on the organic reaction mechanisms' content and learning objectives (Item 3.2). In this aspect, the experts were optimistic that the model is realistic in directing the implementers of the curriculum to use a network of interrelationships of learning activities in the development of a module for teaching organic reaction (Item 3.6). The experts also consensually agreed that the model shows how symbolic language could promote and conceptualize learning through an explicit explanation of the meanings of special terminologies used for teaching organic reaction mechanisms (Item 3.8). This result was paralleling their agreement on the way how the model shows connections of the instructional activities to aid students' understanding through mechanistic reasoning in achieving their learning goal and overcoming students' common errors (Item 3.9). Similarly, the model may be used to guide lecturers in preparing lessons to promote the learning of students (Item 3.10) and, as an example, to develop teaching models for another subject (Item 3.11). Finally, the participants' high agreement on the logical arrangement of the model elements for designing organic reaction teaching module (Item 3.12). The overall charted results for all the three sections above invalidating the ORTM could be concluded in Table 6.



Item	Average Response			Fuzzy Evaluation			Defuzzification	Ranking
1.1 Instructional activities	12.00	13.70	14.00	0.867	0.983	1.00	13.20	1
2.1 Grouping of instructional activities into the five constructs	0.786	0.929	0.986	11.00	13.00	13.80	12.6	4
2.2 List of instructional activities under the language symbolisms construct	0.786	0.936	0.993	11.20	13.30	14.00	12.8	3
2.3 List of instructional activities under the crosscutting concepts	0.829	0.964	1.000	11.60	13.50	14.00	13.0	2
2.4 List of instructional activities under the mechanistic reasoning construct	0.786	0.929	0.986	11.00	13.00	13.80	11.4	17.5
2.5 List of instructional activities under the visual representation construct	0.786	0.936	0.993	11.20	13.30	14.00	12.2	10.4
2.6 List of instructional activities under the reflection construct	0.829	0.964	1.000	11.60	13.50	14.00	12.2	10.4
3.1 The domains classification of the model is based on the error patterns in organic reaction mechanisms.	0.743	0.914	0.993	10.40	12.80	13.90	12.4	6.5
3.2 The model constructs are based on the organic reaction mechanisms content and learning objectives	0.757	0.929	1.000	10.60	13.00	14.00	12.5	5
3.3 The model shows a guide on how an organic 0.629 reaction mechanism could be taught to avoid students' common errors.		0.829	0.964	0.629	0.829	0.964	11.3	19
3.4 The model shows a guide on how the organic 0.686 reaction mechanism could be taught to interfere with students' common errors		0.886	0.993	0.686	0.886	0.993	11.9	15
3.5 The model shows a guide on how an organic 0.657 reaction mechanism could be taught to correct students' common errors.		0.850	0.971	9.20	11.90	13.60	11.7	16
3.6 The model is practical in guiding the curriculum implementers to use a network of the interrelationship of learning activities in developing a teaching module	0.714	0.900	0.993	10.00	12.60	13.90	12.2	10.4
3.7 The model indicates how students' errors could be integrated into the lesson to form a holistic learning experience	0.657	0.836	0.943	9.20	11.70	13.20	11.4	17.5
3.8 The model shows how symbolic language could promote and conceptualize learning through an explicit explanation	0.714	0.900	0.993	10.00	12.60	13.90	12.2	10.4

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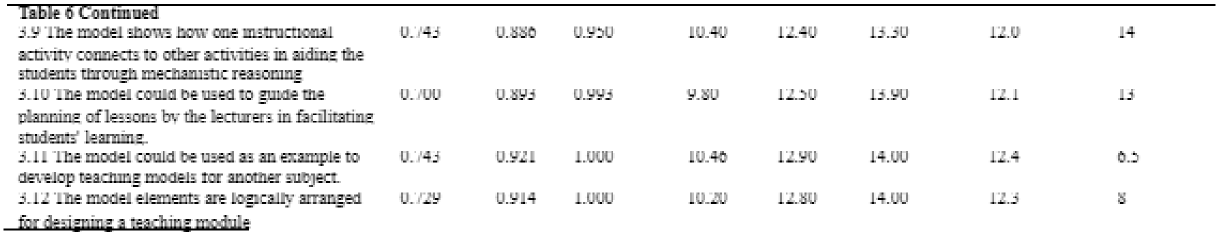

Table 6 Continued

3.9 The model shows how one instructional activity connects to other activities in aiding the students through mechanistic reasoning	0.743	0.886	0.950	10.40	12.40	13.30	12.0	14
3.10 The model could be used to guide the planning of lessons by the lecturers in facilitating students' learning.	0.700	0.893	0.993	9.80	12.50	13.90	12.1	13
3.11 The model could be used as an example to develop teaching models for another subject.	0.743	0.921	1.000	10.46	12.90	14.00	12.4	6.5
3.12 The model elements are logically arranged for designing a teaching module	0.729	0.914	1.000	10.20	12.80	14.00	12.3	8

Table 6 Ranking of the Experts' Collectives Opinion on the Overall Items

item with the approval of the highest consensus experts consistent with the highest value of defuzzification reported for the item. In comparison to traditional Fuzzy Delphi, where the ranking of the items is to decide the variables for the studied. Items with higher ratings may be treated as a component or element selected as a result of the study. The ranking was used in this study to compare the consensus level of experts on every item. From Table 6, item 1.1 (the total list of instructional practices suggested in the ORTM is ranked first in the priorities of experts, while item 3.3 (the model shows a guide on how to teach an organic reaction mechanism) obtained the lowest rating in the collective opinion of experts.

Conversely, the defuzzification values for the ORTM validation questionnaire items were the most interesting findings of these validation processes. In general, based on the findings presented, the defuzzification values met the minimum value of 9.8 for all evaluation questionnaire items (see Table 2), and the results revealed conclusively that the experts decided by agreement on the three dimensions of the validation of the model. Therefore, ORTM is appropriate to serve as a reference in the application of the chemistry curriculum as additional instructional support for teaching organic reactions, based on the collective opinion of experts in this study. The validation phase involved usability assessment of the ORTM based on pre- university lecturers' opinions in terms of evaluating the suitability of the instructional activities and employing the model constructs and domains on improving students' conceptual understanding of reaction mechanisms. Moreover, by evaluating the structural model, the usability of the ORTM in the chemistry classroom was assessed. Cantered on the aforementioned research questions, the model was validated according to three aspects as follows:

- The suitability of the ORTM instructional activities.
- The classification of instructional activities into five constructs: language symbolism, characteristics of crosscutting concepts, mechanistic reasoning, visual representation, and reflection activities.
- The suitability of the ORTM for teaching and learning of organic reactions.

Table 6 also provid

indicated that the three validation aspects had been collectively accepted by the experts. his showed that the experts agreed that the ORTM is sufficient for pre-university students to be used as a reference and learning support.

CONCLUSION AND RECOMMENDATIONS

In this review, the proposed ORTM was validated using the collective opinion of experts by the use of the modified Fuzzy Delphi Technique. The validation was carried out by two key steps: validating the components of the model as, constructs, and sub-construction (instructional activities) and validating the model's usability. The model validation results showed a strong degree of convergence on all facets of the validated model. It was therefore concluded that the ORTM is sufficient to serve as a reference in implementing the model's sub- constructions (educational activities) and as instructional support for chemistry students in studying the principles of organic reaction mechanisms by integrating language symbolisms, mechanistic reasoning, visual representation, and reflection activities.

in describing how students' errors can be used as repairs to avoid, interfere and correct the errors from occurring in the future and meet their learning needs. The model also supports the Johnstone triplet Model of Chemical Representation (Johnstone, 1993) and Threshold Concepts Theory (Meyer Jan & Land, 2005) through the integration of the symbolic, mechanistic, representative, and reflective activities as described in the model. The ORTM activities were described as educational support for learning mechanisms of organic reactions that were highlighted by student experiences, learning material, course teachers, and learning outcomes. The model demonstrated that different types of instructional activities are expected depending on the levels of experiences and the autonomy of students in the many stages of the learning process (Muqsith, Zaharah, Farazila, Yusof, & Mohd Ridhuan, 2017).

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