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Displaying A Macroscopic View of Phase Transition Using A Concrete Model

Faezatul Alwani Binti Mohd Rahim & Muhd Ibrahim Bin Muhamad Damanhuri
Sultan Idris Education University, Perak, Malaysia
Corresponding Author's Email: muhdibrahim@fsmt.upsi.edu.my

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Abstract
This study is intended to develop a concrete model, namely the Fountain of Phase (FOP), in order to assist the students' understanding of phase transition at a macroscopic representation. The FOP model is built based on the ADDIE instructional design model, consisting of Analysis (A), Design (D), Development (D), Implementation (I), and Evaluation (E) phases. A panel of educational experts from Sultan Idris Education University (UPSI) has been appointed to evaluate the usability of the FOP model. The results show that the FOP model obtained a high percentage of agreement, exceeding 70% for the aspects of usefulness, suitability, design, and user-friendly properties. As a conclusion, this study has developed a concrete teaching aid that is valid and usable for the phase transition topic. It is also recommended to solicit feedback from the students in the future.
Keywords: Concrete Model, Macroscopic, Matter, ADDIE, Chemistry, Development.

Introduction
Theoretically, matter occurs naturally in five states known as solids, liquids, gases, plasma (Nandkumar, 2014), and Bose-Einstein condensates (Li et al., 2017). However, only three states of matter are highlighted in the Malaysian chemistry syllabus. The theory regarding the matter was initially introduced to Year 5, 11-year-old students in primary school (Malaysian Ministry of Education, 2012). Students aged 13 or older frequently learn the matter's topic as it is implemented in the science syllabus. The latter level of Malaysian education includes the Matriculation Programme in Malaysia and the Malaysian Higher Education Certificate; STPM, which also deliver the concept of matter broadly.

Literature Review
Understanding the physical state of each phase (solid, liquid, or gas) was easier to assimilate into students' understanding macroscopically because it can be observed with the

naked eye (Maarten et al., 1998); however, it was difficult to associate with the submicroscopic level that requires students' understanding of molecule interaction that led to phase changes (Farida et al., 2017). As a result, the student has misconceptions about molecule reactions, physical and chemical changes in matter, and the systems of atoms, molecules, and particles (Hadenfeldt et al., 2015). Therefore, learning about the states of matter is supposedly not a verbal instruction only, instead involves the use of other learning methods, including experimental methods and the use of teaching aids.

Since the topic of phase changes in the state of matter could be observed at a macroscopic level and needed a student to engage with the real phenomenon, it was also included in the science practical session. Thus, experimental methods are best suited to cater to this situation. According to research conducted by Cobun (1968), students were able to absorb 50% of what they heard and saw because messages received through multiple senses are better understood and retained (Kapur, 2018). Providing the learning session with the ability to allow the students to observe and gain direct experience with the phenomena should not be ignored. The Fountain of Phase (FOP) model offers the same function as the experimental method, which provides a macroscopic view of the phase transition process. Therefore, using the FOP model as a teaching aid in explaining the phase change process is essential, as it allows the student to conceptualize the process by providing a clear image of the processes that can be seen with the naked eye.

A number of new teaching aids have arisen to help students achieve conceptual understanding regarding the matters' topic. Example of teaching aids in the form of models includes computer modeling (Wei et al., 2012), interlocking toys building blocks (Geyer, 2016), students-generated animations on identifying the nature of phase changes (Yaseen & Aubusson, 2018), and a gas-simulator using smartphones to study the learning behavior of gas (Ibrahm & Harun, 2020). However, no concrete model tools regarding the phase transition process are currently available. Therefore, there is a need for model development in order to fill the research gap regarding the conceptual understanding of phase change in the state of matter.

The goal of this research is to built a concrete model called Fountain of Phase (FOP) that incorporates the processes of melting, boiling, freezing, condensation, sublimation, and deposition. The model is then validated by an expert panel of chemistry educators at UPSI.

Methodology

The study's methodology is divided into two parts. The first part deals with developing the FOP model. The second part involves determining the FOP model's validity.

a. Research Design

The development research design applies to this study. The FOP model that is developed based on the ADDIE model applied quantitative methods for the validity data collections processes.

b. Respondents

Researchers use five (5) panels of experts, including the subject matter experts, the lecturers in the chemistry education field, and lecturers with experience in developing teaching aids (Table 1). That panel of experts has a minimum of three (3) to ten (10) years of experience in their field.

Table 1
Expert Background for Model's Validity

Expert	Background
A	Chemistry Department Lecturer at Sultan Idris Education University (UPSI)).
B	Chemistry Department Lecturer at Sultan Idris Education University (UPSI).
C	Lecturer who has the experience in representation teaching aids development.
D	Physics Department Lecturer at Sultan Idris Education University (UPSI).
E	Lecturer in Creative and Arts department in Sultan Idris EducationUniversity (UPSI).

c. Model's Development

By referring to the ADDIE model, the procedure for constructing the model until the validity data is obtained is completed. ADDIE proposed five (5) phases research implementation; which are analysis, design, development, implementation, and evaluation.

i. Analysis

The need analysis questionnaire is distributed to the science and chemistry teachers in the area of Muallim, Perak, Malaysia. In order to create a concrete model, the feedback from the need analysis and feedback from several experts were gathered. As a result, a few distinct characteristics were highlighted: easy to carry, non-harmful, attractive, and capable of stimulating the learning process. The shape, size, and materials needed for the prototype are decided during the design phase.

The need analysis also inquires about the method that the teacher uses as a teaching aid when describing the phase transition process of matter. The results show that the "Plate Model" is used as the concrete model by the teachers to explain the phase transition process (Table 2). Based on the informal conversation, the researchers found that it is the self-created teaching aids by the teachers themselves that are able to create more effective learning sessions and are easy to carry everywhere. The respondents also mentioned that they are inserting the animated video during the teaching and learning session (Table 2). However, using animated video as a teaching aid may take more time and money. Respondents also stated that when using that method of teaching, they require equipment such as a projector and technological skills.

When asked about the content knowledge, 64% of the teachers stated that questions on the topic are crucial to be asked in the examination (Table 2). This implies that the issues surrounding students' understanding of the concept of matter, especially at the lower level of education, should not be taken lightly. The teachers also assert that students need to apply higher-order thinking skills in order to answer the examination questions regarding the matter's topic. The last item of the questionnaire is to gauge their interest in the concrete model that will be developed by the researcher. According to the findings, all teachers are interested in teaching aids in the form of concrete models to help them increase their students' understanding of the matters' topic.

Table 2
Need Analysis Results

Statement	Feedback
Does the state of matter's topic require the students to think more critically in order to answer the exam questions?	Yes : 79% No : 21%
Is it necessary to ask questions about the state of matter's topic during the examination?	Yes : 64% No : 36%
State the method or model that you use as a teaching aid when describing the phase transition process of matter.	Plate Model, Animation Video
Are you interested in using a model or teaching aid in the form of a model that consists of all the phase transition processes as a teaching aid in class?	Yes : 100% No : 0%

ii. Design

The researcher begins sketching the concrete model while receiving feedback from the needed analysis; the pattern and shape of the FOP model, including materials and measurements, are decided during this phase to make it applicable in the teaching and learning session. Figure 1 shows the drawing of the FOP model. The main focus is to build a concrete model that can demonstrate the phase change processes of melting, boiling, condensation, freezing, sublimation, and deposition. The FOP model consists of three (3) sections: the solid tank, boiling tank, and freezing tank. Each tank is designed uniquely with different concepts and technologies. The tanks are instead grouped together on the same base.

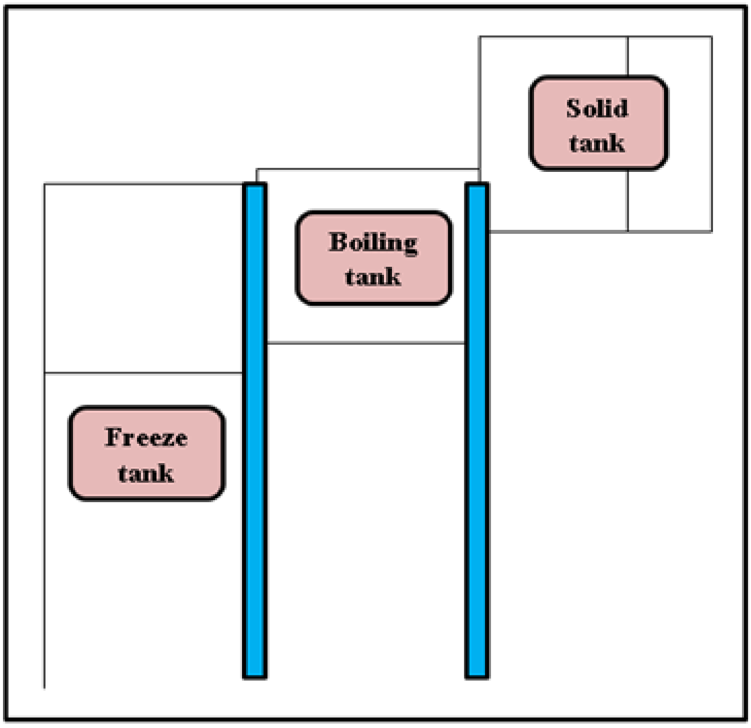

Figure 1. Draft of the FOP Model.

iii. Development

The model development process necessitates close attention because it includes numerous revisions and improvisations to ensure that the model can depict all phase transition processes. The model's development could have taken up to twelve (12) months. The basic materials and instruments used are as stated below:

Materials : Clear Perspex (2.5 mm x 4” x 8”), Silicone Glue, Gasket Silicone Glue, Beaker 100 ml, 10mm Aluminium tube, Bunsen Burner, Beaker 50 ml, Filter funnel 90mm, Bunsen Burner, ¼” x ¼” Mini ball (Copper) valve, 5/16” Cross Tee Balb, 8mm (5/16”) x 1mm x 30m PVC Hose.

Instruments: Bosch GST 80 PBE Jigsaw, Arboga A2608 Range Gear Head Drilling machines.

The main material used to build the solid tank is acrylic sheet (clear perspex). The perspex is cut with the Bosch GST 80 PBE Jigsaw. Then, as shown in Figure 2, a square-shaped container is formed. The solid tank can demonstrate melting, sublimation, and deposition processes. A bowl of ice is poured into the tank's left side (section B). When the ice begins to melt and flow into the liquid tank, the melting process is clearly visible. To speed up the melting process, a small amount of water is sprinkled onto the ice. While the sublimation and deposition processes can be demonstrated using dry ice on the tank's right side (section A). The physical state of dry ice, which sublimates immediately at room temperature, demonstrates sublimation. A piece of copper is partially immersed in the dry ice tank. Copper loses thermal energy when it comes into contact with dry ice. The copper comes into contact with water vapor from the environment. The copper then absorbs thermal energy, converting the vapor to ice. The deposition of matter occurs when ice (solid) forms on the upper side of the copper.

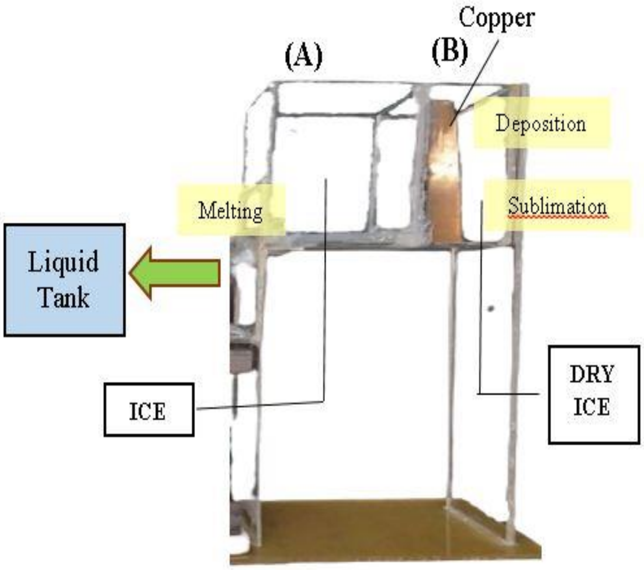

Figure 2. Solid Tank.

Meanwhile, the materials used in developing the liquid tank are glass, stainless steel, and aluminium, which have good thermal properties. A glass filter funnel with a diameter of 75 mm has been modified by adding the vapor collector, which consists of three holes. It is then attached to the glass filter funnel by using silicone glue. The gaskets' silicone glue is then used to secure the stainless steel tube to the hole. Figure 3 shows the shape of the liquid tank. The processes of boiling and condensation or vaporization are shown in this tank. When the liquid from the melting process enters the boiling tank, it fills the beaker. The beaker is heated using the Bunsen burner. The water is boiled until the vapor touches the upper parts of the funnel, demonstrating the condensation process. Students can easily see how the liquid can transform into gas through the boiling process.

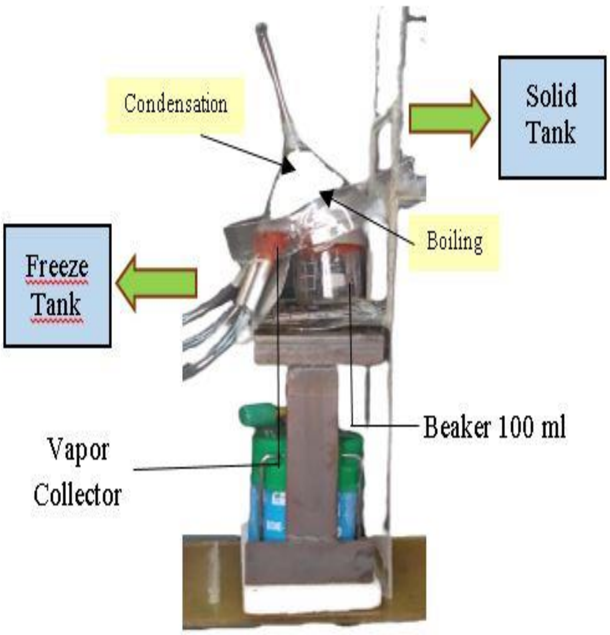

Figure 3. Liquid Tank.

The freeze tank is added to demonstrate the freezing (liquid to solid) process. The outer and inner layers of the tank are made of polystyrene and perspex, respectively. A 50-ml beaker is connected directlyto the PVC hose and placed in the tanks' center. The dry ice is placed around the beaker to freeze the water. Figure 4 depicts the overall design of the freeze tank. The water vapor collected from the liquid tank flows into the freeze tank beaker via the PVC tube. Then, the dry ice is placed around the beaker, causing the water to freeze after about 5 - 10 minutes.

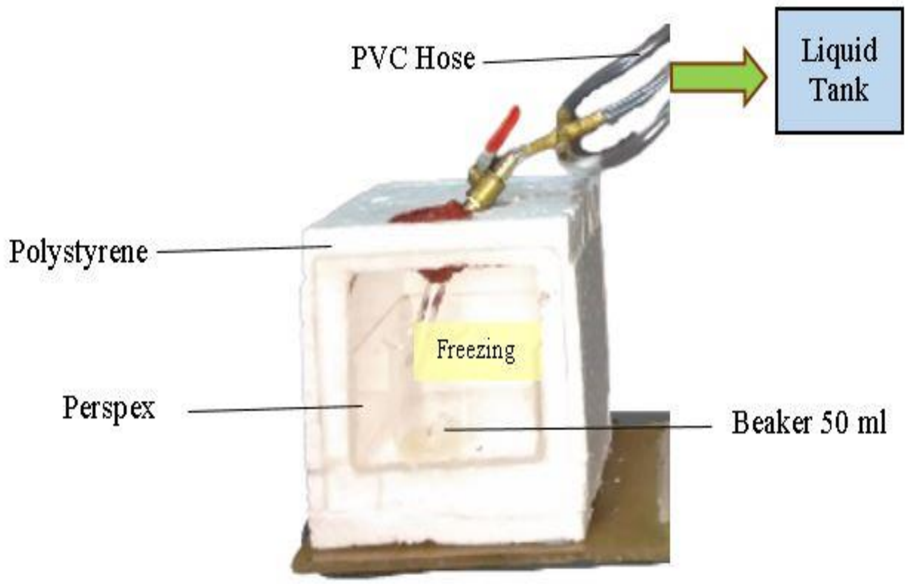

Figure 4. Freeze Tank.

When solid, liquid, and freeze tanks are successfully constructed, all of the parts are combined to produce one model. A 4mm thick perspex sheet is cut and used as the model's stand and base. The tank is then attached to it with liquid chloroform. The phase change process at each tank is depicted in Table 3.

Table 3
The Phase Change Process at Each Tank

Tank	Materials	Phase Change Process
Solid	Perspex	Melting, Sublimation, Deposition
Liquid	Glass, Aluminium, Stainless Steel	Boiling, Condensation/Vapourization
Freeze	Polystyrene, Perspex, Glass	Freezing

iv. Implementation and Evaluation

A panel of experts is approached to provide feedback on the model appropriateness, which includes subject matter experts, lecturers in the field of chemistry education, and lecturers with 3-10 years of minimum experience in teaching aids. The Model Validity Questionnaire (MVQ) contains twenty-five (25) item with four (4) constructs was used as intrument. Construct one (1) is Usefulness & Suitability, required the experts to ensure the ability of the prototype to show the phase transition process and its ability to help the teachers in the teaching process while construct two (2) is Design, required to validate the characteristics of the prototype includes the physical shape, size, and materials used.

Construct three (3) is User-Friendly, which measures the appropriateness of the model towards the user. The last construct consists of an item that conveys the overall aspects, including the consent of experts that the model is a good innovation representative teaching aid.

There are five (5) panels of experts to validate the model, including subject matter experts and lecturers in chemistry in the education field. The data are analysed descriptively by obtaining the percentage of agreement for each construct. The percentage of agreement above 76% is considered very high and acceptable, referring to the development study on concrete teaching materials by (Jessica and Saronom, 2021).

Findings

The process of getting the product validated is important as it helps the researcher or developer identify the product's quality in fitting the needs of the users. Hence, the percentage of agreement (POA) method is used as an indicator for researchers to analyze the response to the FOP model. The value of POA is first calculated for each item of the construct, and then all the POA values of each item are added and divided by the total number to obtain the average of POA for each construct.

Table 4
FOP Model's Validity

Aspect	Item	POA (%)	POA/Ave (%)
Usefulness and suitability	(A1) This model is able to demonstrate all the phenomena of the phase transition process.	100	
	(A2) This model complies with the syllabus of the Standard Based Curriculum for Secondary School Chemistry.	80	
	(A3) This model can increase the quality of teaching and learning sessions.	80	
	(A4) This model can increase student achievement.	60	84
	(A5) This model gives valuable information about the phase transition phenomenon.	100	
Design of the model	(B1) The size of the model is suitable to visualize the process.	100	
	(B2) The physical appearance of the model could attract the students.	40	
	(B3) The materials used in developing the model have quality and are durable.	100	
	(B4) The phenomenon of phase transition processes can be clearly demonstrated.	80	83
	(B5) The design of the model fits the target population.	100	
	(B6) This model is more practical than the experimental method for the phase transition.	80	
	(C1) This model is lightweight.	80	
	(C2) This model is easy to carry everywhere.	40	

User-friendly properties	(C3) This model is not harmful.	80	
	(C4) This model is easy to handle.	40	
	(C5) The use of this model does not require high technological skills.	100	
	(C6) The manual for using the model is easy to understand.	80	71
	(C7) This model corresponds to the time provided.	80	
Overall	(D1) I agree that this model is a good innovative teaching aid for the matter's topic.	100	
	(D2) This model provides new alternatives for the teachers in the teaching and learning sessions for matter's topic.	100	
	(D3) This model can save time in teaching and learning sessions for matter's topic.	100	
	(D4) This model can help teachers.	80	92
	(D5) This model can help the students better understand the phase transition process.	80	

*POA : Percentage of Agreement

Table 5
Experts View Towards the Model

Expert	Comments / Opinion/ Improvement / Suggestion
E1	The physical appearance of the model is less attractive, but the whole model is attractive. This model is not lightweight and is not suitable to carry everywhere unless the researcher prepares a handy box for the model. This model involves the use of dry ice. Hence, the user should be exposed to and aware of the safety risks of handling dry ice.
E2	Overall, the idea of the FOP model is so innovative in linking three phases of matter.
E3	-
E4	The strength of this innovation is that it provides a clear macroscopic view of the phase transition process. Congratulations to the researcher for successfully developing an efficient teaching aid.
E5	This model is very good. It does not require high technological skills or cost.

Discussion

The overall feedback on the first criteria of the model, usefulness and suitability, appeared to have a higher percentage of agreement (POA) from all the experts (Table 4). All the experts agreed (100%) that the model is able to show six basic phase transition processes, which are melting, boiling, condensation, freezing, sublimation, and deposition. They also ratified that the model could give valuable information about the matter's concept macroscopically. Maarteen et al (1998) state that the physical states of each phase (solid, liquid, and gas) are easier to assimilate into students' understanding macroscopically because they can be observed with the naked eye. This implies that the FOP model is perceived to be useful and suitable as an alternative teaching aid to show the phase transition process. Similar to the experiment method, the FOP model is able to provide a concrete learning experience to the student as they can see the real phenomena of the phase transition process with their naked eye (Castillo, 2013).

The idea of the FOP model has received a positive response from the respondents in terms of adding a new innovative teaching aid in the form of a model (refer to item D1 and Table 4). By showing the real phenomena of the process, it may assist the student in generating knowledge in an invisible, submicroscopic world. Treagust et al. (2010) also highlighted that teachers who are using the model in the classroom have the advantage of serving students from macroscopic to submicroscopic and symbolic levels of chemical representation. However, issues arise with the design of the model. An expert has commented that the condensation process is not clearly visualized due to the limited size of the filter funnel. The data also shows that only sixty percent (60%) of the panels agreed that the physicality of the model could attract the students' attention (refer to item B2, Table 4). It is advisable for the researcher to include the improvement in terms of size and physical appearance of the model in the future.

The potential of the model to provide a good experience for the users is also considered in this study. Referring to item number C1 in Table 4, the majority of experts (80%) agree that the model is lightweight. However, the highest percentage of experts disagree that the model is easy to carry everywhere (refer to Item C2, Table 4). Since the model requires the use of several apparatuses, such as a Bunsen burner and dry ice, it is necessary for the researcher to provide proper precautions to the users while using the model, as suggested by expert 1 (E1) in Table 5.

The usage of FOP model is straightforward and easy to understand, as agreed by all the experts, as shown at Item C5 in Table 4. In comparison to other teaching aids, the FOP model is a practical tool that does not necessitate the teacher learning new complicated technological skills. The techniques applied in using the FOP model are analogous to using an experimental method in teaching and learning about phase transition. As a result, teachers do not have to waste time learning complicated technology that may add to their workload. In short, the FOP model is a stress-free teaching aid for teachers, and it can depict the phase transition process in a model.

Therefore, based on the POA value obtained, it is concluded that the majority of experts convey that the FOP model is valid and acceptable for use in the teaching and learning of chemistry.

Conclusion

The study's findings conclude that the FOP, a concrete model for depicting phase transition phenomena in the matter's topic, is valid and potentially usable as one of the alternative innovative teaching aids. The findings also show that the percentage of agreement obtained from the panel of experts is high, exceeding 85% for the constructs of usefulness, ease of use, ease of learning, and satisfaction. According to the data gathered, the majority of experts are impressed with the FOP model. It is suggested that the study be expanded in the future by gaining feedback from students, the model's second users. Students' perceptions of the FOP model, for example, may serve as supporting data to demonstrate that the FOP model is a good alternative teaching aid in the matter's topic.

References

Castillo, M. (2013). The Scientific Method : A Need for Something Better?. *American Journal of Neuroradiology*, 34(9), 1669 – 1671.

Farida, I., Helsy, I., Fitriani, I., & Ramdhani, M. (2017). *Learning Material of Chemistry in High School Using Multiple Representation*. Paper presented at the 2nd Annual Applied Science and Engineering Conference, Bandung, Indonesia. Retrieved from https://iopscience.iop.org/article/10.1088/1757-899X/288/1/012078/pdf

Geyer, M. (2016). Using Interlocking Toy Building Blocks To Assess Conceptual Understanding In Chemistry. Journal of Chemical Education, 94(2), 202–205.

Hadenfeldt, J., Liu, X., & Neumann, K. (2015). Framing students' progression in understanding matter: a review of previous research. *Studies in Science Education*, 50(2), 181–208.

Ibrahm, D. & Harun, A. (2020). Behaviour of Gas Simulator: Using Smartphones to Learn Submicroscopic Level Chemistry. Jurnal Dunia Pendidikan, 2(2), 110-122.

Jessica, C., & Saronom, S. (2021). Development of Sets-Based Chemistry Teaching Materials and Student Responses To Teaching Materials on Hydrocarbon Materials. *Journal Scientia*, 11(1), 2301 – 0059.

Kapur, S. (2018). *Module : Teaching Aids: Non-conventional and Modern*. MHRD Govt. of India.

Li, W., Arshad, Y. (2014). Wait-Time and Multiple Representation Levels in Chemistry Lessons, *The Malaysian Online Journal of Education*, 2(2), 45-53.

Maarten, W., Peter, R., Henny, P., & Ton, J. (1998). *Advances In Learning And Instruction Series : Learning With Multiple Representations*. Elsevier Science Ltd.

Malaysian Ministry of Education. (2012). Chemistry Fom 4, 5 Curriculum Specification KBSM. Putrajaya: Curriculum Development Department, Malaysian Ministry of Education.

Malaysian Ministry of Education. (2012). Chemistry Form 4 Curriculum Specification KBSM. Putrajaya: Curriculum Development Department, Malaysian Ministry of Education.

Malaysian Ministry of Education. (2012). Science Form 1, 2, 3, 4 Curriculum Specification KBSM. Putrajaya: Curriculum Development Department, Malaysian Ministry of Education.

Nandkumar, N. (2014). Plasma – The Fourth State Of Matter. *International Journal of Scientific & Technology Research*, 3(9), 2277-8616.

Polit, D. F., & Beck, C. T. (2006). The Content Validity Index : Are You Sure What's Being Reported? Critique and Recommendations. *Research In Nursing Heath*, 29(5), 489-97.

Treagust, D., Chittleborough, G. & Mamiala, T. (2010). The Role of submicroscpic and symbolic representations in chemical explainations. *International Journal of Science*, 25(11), 1353-1368.

Wei, S., Liu, X., Wang, Z., & Wang, X. (2012). Using Rasch Measurement To Develop a Computer Modeling-Based Instrument To Assess Students' Conceptual Understanding of Matter. Journal of Chemical Education, 89(3), 335-345.

Yaseen, Z., & Aubusson, P. (2018). Exploring Student-Generated Animations, Combined with a Representational Pedagogy, as a Tool for Learning in Chemistry. Res Sci Educ, 50, 529-548.