Asian Social Science; Vol. 14, No. 11; 2018
ISSN 1911-2017 E-ISSN 1911-2025
Published by Canadian Center of Science and Education

Scientific Argumentation in Chemistry Education: Implications and Suggestions

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Received: August 1, 2018 Accepted: September 1, 2018 Online Published: October 22, 2018

doi:10.5539/ass.v14n11p16 URL: https://doi.org/10.5539/ass.v14n11p16

Abstract

The Malaysia Education Blueprint 2012-2025 reveals the aspiration of government to prepare Malaysian children to meet the challenges of a 21st century economy. Nonetheless, Malaysia has a long way to go to achieve this target. PISA (2015) result indicates that Malaysian students have problems in reasoning skills. To achieve the target, Educational Blueprint advocates infusion of inquiry-based instruction in classrooms for students to acquire critical thinking skill. Critical thinking skill is a 21st century learning skill the students need to possess in today's global economy. This skill includes the ability of individual to reason effectively. Scientific argumentation is a skill to promote critical thinking of students. Being the essential element of scientific inquiry and important activity in scientific reasoning, scientific argumentation helps students to develop and refine scientific knowledge. It is imperative to implement scientific argumentation in science classrooms. The purpose of this paper aims to raise some issues, including the results of previous studies about the impact of scientific argumentation on science achievement, the rationale for focusing on monological models in the three classification of argumentation models, and address the issues about the appropriateness of Toulmin argument model (an example of monologoical models), which is prevailed in science education to promote students' scientific argumentation skills. Finally, this paper will outline some suggestions regarding implementation of Toulmin argument model to promote scientific argumentation in chemistry education.

Keywords: scientific argumentation, chemistry education, Toulmin model

1. Introduction

The most recent education policy, Malaysia Education Blueprint 2012-2025 has been approved by the Cabinet in 2013. The blueprint has mentioned the goal for Malaysian education quality is to be in top third of countries in terms of performance in international educational standards in less than a decade by 2025 (Ministry of Education, 2012, p. E-9). It reveals the aspiration of government to prepare Malaysian children to meet the challenges of a 21st century economy. Nonetheless, the result from Organisation for Economic Co-operation and Development (OECD, 2016) shows that in PISA 2015 test, Malaysia's score in Science (443) is below the international and OECD average (493) (Jackson, 2016). The PISA 2015 result indicates that Malaysian students have problem in reasoning skill.

In an effort to promote this goal in education, the Educational Blueprint advocates infusion of inquiry-based instruction in classrooms for students to acquire critical thinking skill. Critical thinking skill is a 21st century learning skill the students need to possess in today's global economy. It leads the students to sift through a substantial amount of information to plan tenable ideas for their actions. This skill includes the ability of individual to reason effectively (NEA, 2012). In science education, scientific argumentation is the main practice in this field to promote reason ability. Scientific argumentation is a process in which the learners engage themselves to propose, support, critique, refine, justify, and defend their position about issues (Llewellyn, 2013). As a result, scientific argumentation enables the learners to understand how to assess scientific knowledge and generate new knowledge.

Scientific argumentation is the essential element of scientific inquiry (Llewellyn, 2013). Previous research shows that emphasizing on scientific argumentation in inquiry instruction boost students' academic performance and better understanding in science subject (Walker, 2011; Hasançebi & Günel, 2013; Demirbag & Gunel, 2014; Celep, 2015; Demircioglu & Ucar, 2015). Among the models of argumentation to stimulate arguments in science classrooms, Toulmin argument model is the prevailed model which has been used by many scholars' in their researches (Böttcher & Meisert, 2011; Nussbaum, 2011; Erduran & Jiménez-Aleixandre, 2012; Foong & Daniel, 2012; Karişan, 2015). Despite the prevalence of Toulmin model, formal logicians question about the validity of Toulmin's scheme (Foss & Trapp, 2002; Driver et al., 2000; Upshur & Colak, 2003; Hitchcock & Verheij, 2006; Fox & Modgil, 2006; Lin & Mintzes, 2010; Nussbaum, 2011). Besides that, some researchers report the students face difficulties to distinguish the elements in Toulmin model, especially the evidence from warrant (Lin & Mintzes, 2010; Sampson & Walker, 2012; Hasnunidah et al., 2015).

Toulmin (2003) views argument is field-dependent, means that the acceptability of the content in arguments depends on the subject matter. Chemical knowledge is learned at three levels of representation: macroscopic, microscopic and symbolic. These three levels are called "The Chemical Triplet" which describes the method to understand science knowledge (Johnstone, 1993; Dori & Hameiri, 2003). Professional chemists work well inside these three types of chemical representation mode (Johnstone, 1993). Therefore the combination of this mode helps the chemistry learners acquire chemical knowledge and enrich their explanations of chemical concepts. Toulmin model is ubiquitous in science education. However, the questions about its validity and problems of distinguishing elements in this model have to be resolved. This paper resolves these questions in three ways. First, it provides a brief review of issues from previous studies that investigate the impact of scientific argumentation in science achievement. Second, it outlines the conceptual framework of three categories of argumentation model and then the taxonomy of argumentation model in order to provide an overview of advantages and limit of various argumentation models. Third, it reviews literature on the scholars' critics and comments on Toulmin model. From these reviews, the appropriateness to apply Toulmin model in science education are discussed. Fourth, arguing that the Toulmin model is field-dependent, the nature of chemistry is highlighted. Then this paper shows how chemical triangle complements with Toulmin model to facilitate chemistry learners distinguish the elements in the Toulmin model.

2. Impact of the Natural Element of Scientific Inquiry: The Scientific Argumentation for Science Achievement

In an ever-changing highly technical society, thinking skill is necessary for students to process vast quantities of information successfully (Robinson, 1987, cited in Kremer, 2011). To promote thinking skill, the encapsulated Education Blueprint suggests infusion of inquiry approach in classrooms. Some issues however, are arisen from that. The issues of how thinking skill is acquired, developed and performed through inquiry have to be explored.

Inquiry-based instruction is not a new pedagogical method. As early as 1910, John Dewey has recommended it into K–12 science curriculum (Dewey, 1910). Inquiry is an interactive process which provides excellent means for students to achieve the scientific concepts through conducting research investigations. This process includes formulating a question, developing a hypothesis, conducting an experiment, recording data, analyzing data, and drawing conclusions (NRC, 1996). As a result, inquiry instruction approach offers students the opportunities to think as scientists.

The impact of inquiry-based instruction on academic performance has been investigated. A number of studies (Şimşek & Kabapinar, 2010; Ugwuadu, 2010; Witt & Ulmer, 2010; Opara, 2011; Hussain et al., 2011; Ergül et al., 2011; Taylor & Bilbrey, 2012; Thoron & Myers, 2012; Njoroge et al., 2014; Abdi, 2014; Singh, 2014) reported that utilizing inquiry-based instruction in science classrooms enhance the students' academic performance. Nonetheless, there are researches are inconsistent with these findings (Wild, 2012; Miller, 2014; Wu et al., 2014; Hashim et al., 2015; Maxwell, 2015). The findings of research indicate that students' performance in science is not promoted by having them practice and participate in the inquiry-based activities.

National Research Council (NRC, 2000) articulates the five essential characteristics of inquiry-based learning environment: a) learner participates in scientifically oriented questions; b) learner answers questions based on evidence; c) learner uses evidence to formulate explanations; d) learner links explanations to scientific knowledge; and (e) learner communicates to justify their explanations. These five essential characteristics of inquiry exist in the process of scientific argumentation which is a natural element of scientific inquiry (Llewellyn, 2013). In this process, the students use critical-thinking skill to help them propose, support, critique, refine, justify, and defend their position about issues (Llewellyn, 2013). Through this process, students' scientific reasoning and scientific knowledge are developed and refined (Grooms et al., 2015). As a result, infusion of scientific argumentation is a key to determine the success of inquiry-based classrooms. Omitting it can lead to inefficiency of inquiry classroom.

Within a conceptual framework, infusion of scientific argumentation in inquiry learning can lead to important outcomes in the science classrooms. For example, Hasançebi and Günel (2013) found that chemistry students taught with argumentation-based inquiry approach outscored in tests than those who taught with traditional teaching approach. This study, as well as related work (Demirbag & Gunel, 2014; Demircioglu & Ucar, 2015; Nilgün, 2015) shows that argument-based inquiry is a better approach than the conventional strategy to enhance science students' academic performance. Another benefit that argument-based inquiry learning offers are development of reasoning skills and empowers students to talk and write the language of science (Jiménez-Aleixandre & Erduran, 2008), development of scientific attitude that enable the students to develop and support a valid conclusion with genuine evidence (Walker, 2011), and improvement of argumentation and critical thinking skills among the low and high academic ability students (Hasnunidah et al., 2015).

The above finding shows that scientific argumentation in inquiry learning involves the students to use critical thinking skill to make informed decision, thus boosting their academic performance. In spite of this meaningful talking activity promotes learning in science, Ogan-Bekiroglu and Eskin (2012) reported the argumentative activities caused gradual increase in terms of quality and quantity of arguments made by students but not the conceptual growth in conceptual knowledge. On the other hand, Aydeniz et al. (2012) attested the positive effect of scientific argumentation to improve students' quality of arguments and conceptual understanding in the topic of properties and behaviours of gases. However they found that the students' ability to make argument and knowledge did not develop at the same time. As a result, Aydeniz et al. (2012) were not sure the same effect as shown in their findings would be occurred when testing students with other topics.

3. The Conceptual Framework of Three Categories of Argumentation Model and Taxonomy of Argumentation Model

In recent years, scientific argumentation has attracted the most scholarly attention for how it enhances learning in science. It has been used in different areas such as proof elaboration, informal reasoning, knowledge elicitation, scientific explanation, and knowledge representation (Venville & Dawson, 2010; Aydeniz et al., 2012; Bulgren et al., 2014; Çelik & Kılıç, 2014; Çınar & Bayraktar, 2014; Demirbag & Gunel, 2014; Acar, 2015; Demircioglu & Ucar, 2015; Hasnunidah et al., 2015; Heng et al., 2015; Chen et al., 2016; Hakyolu & Ogan-Bekiroglu, 2016; Chen & Looi, 2017). Many argumentation models have been developed to investigate argumentation process, for example, Toulmin model, Breton's model, Amgoud et al.'s model, etc. What argumentation model is suitable to address specific needs in a field is a question that needs to be resolved. As a guide for the researchers to select appropriate argumentation model for their fields, Bentahar et al. (2010) had proposed taxonomy of argumentation models through reviews of many important argumentation models, approaches and systems found in the literature. Bentahar et al. (2010) were then categorized the argumentation model into three categories of models: rhetorical models, dialogical models, and monological models. The conceptual framework of these three categories of argumentation models are summarized in Table 1 below:

Table 1. The conceptual framework of three categories of argumentation models

Model / Conceptual framework	Rhetorical Models	Dialogical Models	Monological Models
Structure	Rhetorical structure of arguments	Macro structure of arguments	Micro structure of arguments
Foundation	Audience's perception of arguments	Defeasible reasoning	Arguments as tentative proofs
Linkage	Connecting arguments in a persuasion structure	Connecting a set of arguments in a dialogical structure	Connecting a set of premises to a claim at the level of each argument

(Source from Bentahar et al., 2012)

According to Bentahar et al. (2012), the foundation of rhetorical models is emphasized on the audience's perception than on the argument itself. This type of model concerned with achieving purpose of persuading audiences by appealing them a set of beliefs, rather than general acceptability (Grasso, 2002; Besnard & Hunter, 2008; Bentahar et al., 2012). The dialogical models lay at the foundation of in the argumentation systems the basic notion is that of a defeasible reasoning. It means that the conclusion of an argument is not conclusive as it is subject to being defeated when there is new information overturns the rule that supports the conclusion

(Bentahar et al., 2012). Defeasible reasoning allows incomplete or inconsistent knowledge to be challenged (Pereira et al., 2015; Gazzo Castañeda et al., 2016; Ragni et al., 2017). It is often used in the logic of law (Dung & Sartor, 2011; Gazzo Castañeda & Knauff, 2016) and development of artificial intelligence (Pollock, 1987; Gómez et al., 2010; van Gijzel & Prakken, 2012; van Eemeren et al., 2014; Pereira et al., 2015). This kind of model regards arguments as macro entities; the conflict resolution process is the main concern of dialogical models (Bentahar et al., 2012). A third classification of models, referred to as monological models. This kind of model focuses on the micro structure of arguments, meaning the relationship between the premises. The models built upon a foundation of the arguments are regarded as tentative proofs for propositions (Bentahar et al., 2012).

A convincing argument is first built upon the foundation of interrelation between premises and conclusions, then only taking account the relations between the other arguments which may challenge the conclusion. In some circumstances in which the arguments are produced to achieve some preplanned goals, such as the participating agents' believes, then the audience's perception has to be considered as well (Bentahar et al., 2012). It is thus a good argument includes micro, macro and rhetorical features. Among the three features of an argument (micro, macro, and rhetorical), the micro structure should be addressed at the first level. Then only the next two features are taken into account. As a result, it is important to select an appropriate monological model to produce and start good arguments. This paper compares some popular monological models, in terms of their argument structure, inference rules, advantages, and limit to provide an overview of the models and guideline for the researchers to select argumentation model that accord with the demands of their research topics.

Table 2. Comparison of the monological models (adapted from Bentahar et al., 2012)

No	Models	Argument structure	Inference rules	Advantages	Limits
1	Toulmin and its extensions	Data, qualifier, claim, different types of warrants, backing and rebuttal.	Partially specified using warrants, backing and rebuttal.	The different components of an argument structure and the link between these components are taken into account. Thus they can be used for knowledge elicitation. They are based on philosophical and empirical foundations. They facilitate the construction of textual arguments. They provide an excellent means for knowledge representation. They model the inference rules that are used to infer a conclusion from a set of premises.	They are based on an informal description. Thus, the defeasible rules and the relations between the elements of an argument are sometimes ambiguous. They do not formally specify how the different argument structures can be combined in order to illustrate the dynamics of the argumentation process. The participants and their knowledge bases are not considered. The acceptability criteria of the arguments are not specified.
2	Reed and Walton	Major premise, minor premise and conclusion.	Specified using critical questions.	They illustrate the structure of the arguments using real cases as examples. They can be used for knowledge representation using diagrams. They can be extended for knowledge elicitation. They model the inference and the defeasible rules using the critical questions. They consider different acceptability criteria that are related to the nature of	They are based on an informal logic that does not define the defeasible rules and the argumentation relations. The interaction between the different argumentation schemes is not specified. Even if they can do so, the dialectical structure of the schemes is not clearly addressed and formalized. The criterions used in the taxonomy of the argumentation schemes are only based on the practical observations and not exhaustive.

				the schema.	The participants' knowledge bases are not considered.
3	Anscombre and Ducrot	Topoï	Specified using topos: gradual inference rules.	The notion of topos can be used to illustrate and formalize the link between the premises and the conclusion of an argument. The approach can be used to generate qualitative explanations about the inference rules.	The approach is defined in an informal language and the different argumentation relations are not defined. The theoretical foundations are not clearly stated. It does not offer a deep mechanism for knowledge representation. It neglects the agents participating in the argumentation game. The argumentation process is not illustrated. The different elements are not distinguished and the acceptability criterions of elements are not specified. Thus it cannot be used for knowledge elicitation.
4	Breton	Not specified	Specified using framing and linkage.	It provides a general taxonomy of arguments by defining the link between a macro-view and a micro-view of arguments It models the different levels in the acceptability of arguments and inference mechanism (Authority level, Realignment, deductive level and analogical level).	It does not offer any definition of the argument structure and it does not specify the argumentation process. Consequently, this model is not appropriate for knowledge representation and elicitation. The theoretical foundations are missing. It does not take into account the characteristics of the participating agents.

Table 2 shows the four examples of monological models which are usually apply in the fields of research. The Table 2 indicates that these models have their advantages and limits. As a result, there is no perfect model to promote and measure people scientific argumentation skill. How to choose an argumentation model is thus depending on whether the limits of the argumentation models can be overcome to a certain extent of acceptable limit. The basis of scientific method is all scientific knowledge must be based on observation and investigation (Kosso, 2011). Thus the monological model which is based on empirical foundation must be selected. This paper aims to suggest an argumentation model for the learning in chemistry education. Being a monological model which is built based on philosophical and empirical foundation; Toulmin model models the inference rules that are used to infer a conclusion from a set of premises is thus an excellent means for knowledge representation and knowledge elicitation. This paper suggests Toulmin model to promote scientific argumentation in chemistry learning. From the issues of applying Toulmin's model in science education and the nature of chemistry, the rationale to use apply Toulmin model is further elaborated and the ways to overcome limits of Toulmin model are suggested.

4. Issues and Rationale to Apply Toulmin's Argument Model in Science Education

Scientific argumentation can be used as a tool to hone critical thinking skill (Hussain et al., 2017). It is crucial for students to refine scientific knowledge (Grooms et al., 2015). The previous studies (Ogan-Bekiroglu & Eskin, 2012; Aydeniz et al., 2012) which do not show the obvious effect of scientific argumentation are however, wondering the readers about the tangible benefit to practice scientific argumentation in classrooms. The offbeat findings may due to the process of scientific argumentation is misconducted. It is important to note that scientific argumentation involves the core feature of science that is the coordination of evidence and theory for supporting or refuting an explanatory conclusion (Suppe, 1998; Shemwell & Furtak, 2010). As a result, incapability of students to do so may cause failure of scientific argumentation classrooms.

Among the frameworks of argumentation, Toulmin (1958) model of argumentation is broadly used in the research of science education (Böttcher & Meisert, 2011; Nussbaum, 2011; Erduran & Jiménez-Aleixandre, 2012).There are six elements in Toulmin model.The three elements: claim, grounds, and warrant are primary elements present in every argument; another three elements: backing, rebuttal, and qualifier are added as necessary in arguments (Karbach, 1987). Claim is the basic purpose of an argument or assertion about an issue; data are the evidence that supports the claim; warrant links the data to the claim. It is a reason for making a claim; backing enhances the reliability of the warrant; rebuttal is valid statements that can invalidate the warrant and thus the claim; qualifier modifies the claim (Brockriede & Ehninger, 1960; Karbach, 1987; Toulmin; 1958).

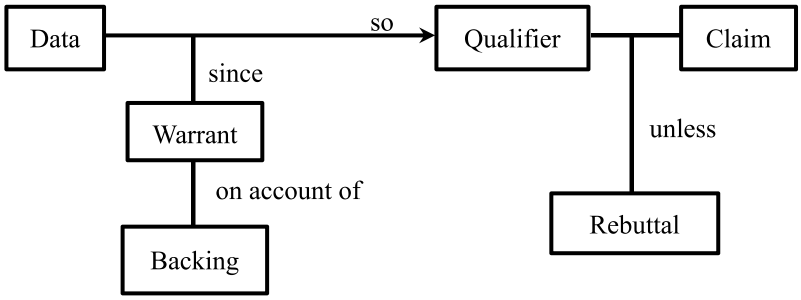

Figure 1. Toulmin (1958) argument framework

Toulmin's argumentation model describes the link between data, claim and how warrant, backing, and qualifier strengthen an argument (Toulmin, 1958; Karbach, 1987), therefore giving detailed analysis the strengths and weaknesses of an argument. In addition, Toulmin incorporates argument fields (field-dependent arguments and field-invariant arguments) to augment his framework (Schroeder, 1997). The conclusion made based on Toulmin model is thus judged by the subject matters (fields) and open to exception. Toulmin model has been applied as an educational tool to improve students' conceptual understanding and assess students' quantity and quality of arguments (Simon et al., 2006; Lin & Mintzes, 2010; Venville & Dawson, 2010; McNeill, 2011;Aydeniz et al., 2012; Hand et al., 2012; Ogan-Bekiroglu & Eskin, 2012; Kaya, 2013; Walker & Sampson, 2013; Yalçın Çelik & Kılıç, 2014; Hasnunidahet al., 2015; Karişan, 2015; Probosari et al., 2016). Even though Toulmin model is generally accepted, it encounters different judgments from scholars.

Formal logicians question about the practical argument focus in Toulmin scheme which is proposed based on probability in a circumstance but not the truth (Foss, 2002). As a result, the validity in Toulmin model for judging argument strength is doubted (Driver et al., 2000; Upshur & Colak, 2003; Fox & Modgil, 2006; Hitchcock, 2006; Lin & Mintzes, 2010; Nussbaum, 2011). Furthermore, Toulmin's idea of conclusion is judged by domain specific standards which are based on subject matters. The conclusion made according to Toulmin model is tentative. However, formal logicians focus on analytical argument. They assume the standards to judge and validate arguments are not varied across the subject matters (Foss, 2002). In making conclusion, they view a conclusion must be made from premises with absolute certainty; no further inferring occurs once information obtained is the part of premises as the information can directly bring to the conclusion (Nussbaum, 2011).

Table 3. The difference between Toulmin and formal logician in their view of the concept of an argument

	Toulmin	Formal Logician
Dichotomy of logos in argument	Practical argument	Analytical argument
Criterion of the conclusion	Based on probability in a circumstance.	Made from premises with absolute certainty.
	Judged by domain specific standards (subject matters).	Standards to judge arguments are the same and never vary across the subject matters

Toulmin (1958) introduces a layout of argument scheme making an argument a more readily understandable fashion. Nonetheless, there are research have reported the difficulties of students to apply Toulmin model in making good arguments. The difficulties of students to apply this model are due to their failure to explain the reasons why evidence support the claim and is included in their arguments (Sampson & Walker, 2012) and students are unable to develop a rebuttal based on adequate data, warrant, or backing (Hasnunidah et al., 2015). These findings indicate that students confuse about the difference between data and evidence is the main reason. Data are the information from an investigation whereas evidence is a subset of data relevant to the question being investigated for supporting or refuting a claim (Llewellyn & Rajesh, 2011). These two terms can be confusing. Even the high achievers do not fully understand the meaning of evidence and mistreat warrants as evidence (Lin & Mintzes, 2010).

Scholars pass different judgments on the Toulmin's argumentation model. Still, this model is ubiquitous and applied in current science education. To ascertain the appropriateness of Toulmin model to promote good argument in science education, the question regarding of its validity has to be resolved. For this purpose, we have to recognize the meanings of inquiry and argumentation in science. If not, our preference would lead us bias to formal logic or informal logic about argumentation. National Science Education Standards defines inquiry is an activity that require learners' ability of critical and logical thinking, and consideration of alternative explanations to make observations, examine and evaluate their proposed explanations from evidence derived from their works (NRC, 1996). Argumentation, on the other hand, is the heart of scientific inquiry (Böttcher & Meisert, 2011), the natural element of scientific inquiry (Llewellyn, 2013) and central role to learn about science (Driver et al., 2000). As a result, the process of scientific argumentation involves justification of propositions consists of observation statements amounting to evidence and expressing standpoint in a theoretically way (Shemwell & Furtak, 2010).

Science is not a matter of knowing universe but a method of guidelines to organize experiences for yielding predictive power (Riegler, 1998). The universe is not knowable but human continuous effort to discover it. Thus, there is no theory is permanently true but overthrown when it faces challenges and fails to explain the phenomenon occurs in its area. For example, from ancient times, people believe that once head is separated from body, human will die; people believe that electrons are orbiting around the central nucleus like Earth revolves around the Sun. However human beliefs are shaken when new knowledge is discovered by scientists. In recent years, head transplant has been a focus of study by neurosurgeon. The neurosurgeon, Sergio Canavero and Ren Xiao Ping had carried out a series of head transplant experiments on animal successfully in 2016 and, they announce the first human head transplant will be carried out in December 2017 (Osborne, 2017, April 27). In the field of quantum mechanics, Bohr's physical model of the atom and subshell assignments are proved incorrect. The electrons are not moving in circle motion but in a secondary quantum number with different shapes. Later, Bohr's electronic configuration is replaced by the secondary quantum number with the series notations (s, p, d, and f) by Friedrich Hermann Hund (Rae, 2007).

The continuous discovery of science knowledge indicates that there is no certainty in science as long as the new knowledge is still discovered. Science only provides us guidelines to organize experiences (Riegler, 1998) but not directly tell us the absolute certainty in this world nor how to use scientific knowledge. Thus it is a mistake to assume that a conclusion is made from premises with absolute certainty and no further inferring occurs. Toulmin's belief that the knowledge is not enduring (Foss, 2002), his criterion of justification is not absolute and there is argument fields in his argumentation framework. It is unquestionably his belief of practical argumentation fulfills the needs of this ever changing world; his argument framework provides people a way to learn how to think outside the box, thus achieving the breakthrough and limitations of science. Toulmin's model may not the best model to promote good argument. However, there is no research finding reports the best argument scheme for science education. If there is some limit in Toulmin's model, the limit is nothing when many scholars (Brockriede & Ehninger; 1960; Locker & Keene, 1983; Karbach, 1987; Hitchcock, 2006; Zarębski, 2009) prove the advantages of Toulmin's model to promote students' learning.

5. Chemical Representation of Matter (Chemistry Triplet) and Toulmin's Model

Toulmin (1958) views the acceptability of the content in an argument depends on the subject matter; there is a criterion there in certain field for people to judge an argument. As a branch of science, Chemistry is the study of the matter, properties, and laws that rule it (Ponce-Espinosa et al., 2014). To understand the abstract concepts in chemistry, professional chemists predominantly work inside chemical representations: macroscopic, sub-microscopic, and symbolic (Johnstone, 1993). The macroscopic level is related to any observable situation; the microscopic level related to behaviour of unseen molecular structures; the representational level records the microscopic level in the form of symbols, formulae, equations, molarity, mathematical manipulation or graphs (Johnstone, 2000). Previous researches show that the ability to interplay between chemical representations promotes students' conceptual understanding (Kirbulut & Beeth, 2013; Yakmaci-Guzel & Adadan, 2013; Sim & Daniel, 2014; Milenković et al., 2016); improving their mental model (Sunyono et al, 2015) and reducing cognitive load (Milenković et al., 2014). The failure to use sub-microscopic approach to interpret and explain a phenomenon in macro-microscopic view cause insufficient construction of the scientific knowledge (Ozmen, 2011) and hence the misconception which handicaps students' learning (Kelly et al., 2010; Surif et al., 2014; Serobatse et al., 2014). As a result, the ability to operate within chemical representation is important to judge a claim in chemistry successfully.

Previous studies (Lin & Mintzes, 2010; Sampson & Walker, 2012; Hasnunidah et al., 2015) show that students do not understand the meaning of evidence. They are unable to provide reasons for their evidences and support claim with observable evidence. Besides that, students, mistreat warrants as evidence. It is thus students have problems to apply Toulmin model is because they do not know the meaning of evidence and fail to distinguish evidence from warrant. In Toulmin model, all arguments begin with data or evidences that support a claim (Warren, 2010). Concept of data is essential to scientific inquiry. Although there is some similarities but the concept of data is different from evidences. Data have to be implied, it is called as evidence. If data is simply taken without interpreted, there will be no informative component in an argument (Brockriede & Ehninger, 1960). Though evidence can be used to justify claim and support conclusion. However when the data is inconclusive, it cannot be the adjudicator of claims (Upshur & Colak, 2003). In this case, warrants are needed to justify connection between data and claim (Driver et al., 2000). Warrant is fundamental to scientific critical reasoning. It is unspoken assumption (rules, principles, inference-licenses) which is brought to the surface through logical inference (Driver, 2000; Warren, 2010). However teaching students to identify warrant is a tough task that sometimes instructors omit warrant from argumentation framework (Warren, 2010).

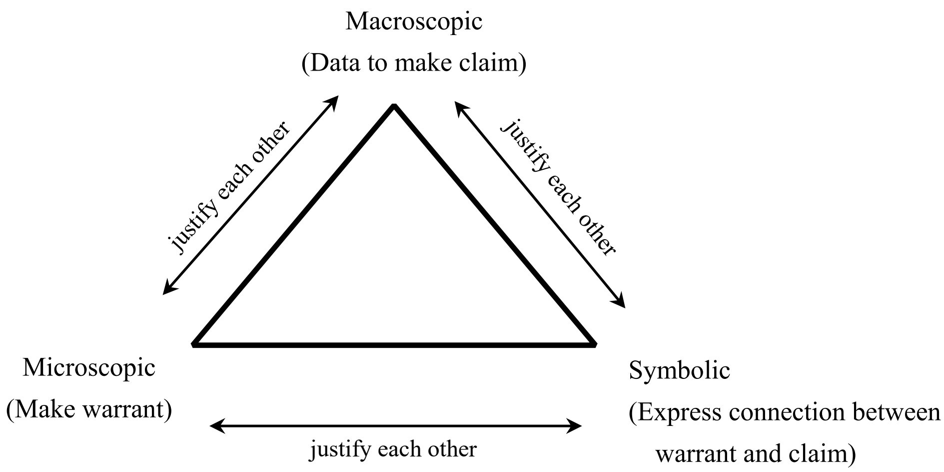

Figure 2. Incorporating Chemical triplet in Toulmin's Framework

The data is about facts and warrant is about rules (Toulmin et al., 1984). From the literature review and findings, it is found that in order to facilitate students use Toulmin's model to make good argument in chemistry, teacher has to teach students how to interpret data and relate sub-microscopic level of chemical representation in making warrant. It is believed that using the chemical triplet as a tool to judge the elements in Toulmin model helps students make good argument in chemistry.

6. Conclusion

Critical thinking skill is a 21st century learning skill the students need to possess in today's global economy. Scientific argumentation is a process to hone this skill (Hussain et al., 2017). To promote this skill in science education, Toulmin's model of argumentation is broadly used (Böttcher & Meisert, 2011; Nussbaum, 2011; Erduran & Jiménez-Aleixandre, 2012). Nonetheless, formal logicians comments that Toulmin scheme is proposed based on probability in a circumstance (Foss, 2002), the validity to judge argument strength (Driver et al., 2000; Upshur & Colak, 2003; Fox & Modgil, 2006; Lin & Mintzes, 2010; Nussbaum, 2011) is thus not convincing.

It is found that there are no study reports the best argumentation scheme for study science education. Furthermore, seeking consensus of an ideal argumentation scheme takes time or at best, results in inferior choices. The general purpose of Science aims to reach consensus between reasoning and argumentation and there are previous studies (Brockriede & Ehninger; 1960; Locker & Keene, 1983; Karbach, 1987; Hitchcock; 2006; Zarębski; 2009) prove the advantages of Toulmin model to promote students' learning. As a result this paper suggest Toulmin's (1958) model that is said broadly used in the study of science education (Böttcher & Meisert, 2011; Nussbaum, 2011; Erduran & Jiménez-Aleixandre, 2012) for chemistry education.

Toulmin et al. (1984) advocates the validity of an argument should not determine by formal logic but the ideas in an argument can survive through critical evaluation. The standard for justifying claim in an argument is premised on the assumption that different fields have different bedrocks that must be obeyed. Chemistry is the study of the matter, properties, and laws that rule it (Ponce-Espinosa et al., 2014). Thus the ability to work inside chemical representations: macroscopic, sub-microscopic, and symbolic is important to understand chemical concept (Johnstone, 1993). To make a claim in the topics related to chemistry, students should be able to justify their claim using the chemical triplet.

Previous studies (Lin & Mintzes, 2010; Sampson & Walker, 2012; Hasnunidah et al., 2015) indicate that students face difficulties to use Toulmin' model because they do not know the meaning of evidence and fail to distinguish evidence from warrant. To solve this problem, students have to know that data is about facts and warrant is about rules (Toulmin et al., 1984). They have to learn how to marshal and interpret data to obtain informative component in an argument (Brockriede & Ehninger, 1960). If the data is informative enough, it is the evidence to justify claim and support conclusion (Upshur & Colak, 2003). However if the data are inconclusive, warrants are needed to justify connection between data and claim (Driver et al., 2000). In this case, students have to know how to make warrant in an argument.

Warrant is unspoken assumption (rules, principles, and inference-licenses) made through logical inference (Driver, 2000; Warren, 2010). Hence, it is not easy to teach students make warrant that sometimes teachers omit warrant from argumentation framework (Warren, 2010). The microscopic level related to behaviour of substances, thus teaching students to make warrant using this level facilitate them to make warrant. Incorporation of chemical triplet in Toulmin model for chemistry learning matches with the Toulmin's concept of field dependent. It is believed that chemical triplet can be served as guideline to judge the elements in Toulmin model and help chemistry students make better arguments.

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