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PAPER

Alternative Framework in Electrochemistry among Secondary Schools Students in Johor, Malaysia

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ABSTRACT

The presence of an alternative framework in the students' minds acts as the main hindrance to students exhibiting profound understanding of scientific concepts, which in turn promotes the application of scientific knowledge to solve daily life context problems. This research is done in two phases. In the first phase, the research aims to identify the alternative framework among students on the concept of electrochemistry, and in the second phase, it develops an instructional module for secondary school students on the concept of electrochemistry by using the five-phase Needham constructivism model approach to overcome the alternative framework that exists in the students' minds. In this paper, however, only the findings of the first phase are reported. The instrument used for this study is the electrochemistry test developed based on previous research and validated by experts. This paper and pencil test is used in the first phase of the research as a data collection tool. This research adapted a quantitative research design. The data from the electrochemistry test is analyzed using statistical packages for social sciences (SPSS) 20.0 to get the descriptive data as findings of the first phase of the study. The findings of the first phase of this study indicate that the conceptualization level of students in electrochemistry is poor. Multiple alternative frameworks among students were identified from the analysis of the students' responses. This study contributed to existing literature by identifying the alternative frameworks present precisely in electrochemistry. The study recommends incorporating mobile technologies in the data collection process and in developing online instructional modules to be more accessible to educators throughout the country and to steer the chemistry education world to a higher level in the Malaysian education system. Enlightening the alternative framework existent in the students' knowledge schemata immensely facilitates educators worldwide in planning their instructional approach in the classroom for this specific scientific concept.

KEYWORDS

alternative framework, misconception, electrochemistry

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1 INTRODUCTION

An alternative framework is defined as an inaccurate conclusion or idea constructed by a learner due to prior knowledge or experiences in specific domains, which differ from scientific knowledge [1]. Alternative frameworks can happen due to incorrect facts or improper construction of knowledge. Alternative frameworks that are developed without any prior knowledge of the discipline are often considered ideas in a student's mind. Students can have some alternative framework in their minds as a result of their experiences acquired before they are exposed to the knowledge. This in turn obstructs the students from constructing the proper structure of knowledge, which hinders their understanding of scientific concepts [2]. Alternative frameworks for certain knowledge or concepts can remain for a long period of time and resist changes. This has a negative impact on the students' subsequent learning process [3]. To promote effective and meaningful learning of chemistry, the students should have a minimum or no alternative framework of theories and concepts [2]. Only in this way will the theories learned be meaningful to the students, and they will establish a deep understanding of the knowledge [4].

According to [5], students may develop alternative frameworks since chemistry is an abstract concept, and to establish appropriate conceptualization of scientific concepts in chemistry, it requires understanding at the macroscopic, microscopic, and symbolic levels. The topics in chemistry are hard to grasp due to the presence of multiple specific terms and their complexity [6]. Due to the abstract nature of chemistry, an alternative framework often exists in the students' knowledge structure. Chemistry is constantly deemed difficult due to the inability of students to grasp the content efficiently. Many of the students have difficulties in understanding the fundamental concepts of chemistry [7]. The alternative framework must be identified by the teachers before conducting the lesson [8]. The alternative framework plays a vital role in the acceptance of the new knowledge learned by the students.

[9] stated that the main factors that contribute to poor conceptualization of scientific concepts include poor background knowledge of students in the particular discipline, misinterpretation of everyday language into chemistry, and the absence of teaching aids. The language used by the teachers is often misunderstood by students. The absence of teaching aids, which are supposed to represent the abstract chemistry concept at the macro, micro, and symbolic levels, causes an alternative framework to be formed in students' minds [9]. In another study, wording and style were known to induce alternative frameworks among students [5]. The choice of words used in the classroom instruction could have meanings differing from the intended purpose, particularly in explaining a scientific concept. It is also stated that teachers may disregard the proper prior knowledge needed by the students to perceive the concepts well [5].

[10], on the other hand, stated that an alternative framework could be caused by students, teachers, and the teaching materials used in the lessons. The students could simply understand the concept inaccurately due to wrong intuition or incomplete reasoning. Incompetent teachers who have not mastered the topics and who do not let the students express their ideas in the class also contribute to formation of an alternative framework among students. Besides that, teaching methods such as lectures that do not incorporate multiple intelligences are the reason for alternative framework acquisition among students. Similarly, in a review by [11], the identified causes of alternative frameworks can be students, teachers, teaching materials, and teaching methods. Teaching materials such as text books and literature could contribute to alternative frameworks by explaining a concept inaccurately.

[8] observes that students' inaccurate preconcept is a reason for them to have an alternative framework for learning chemistry. The self-developed concepts of the students often do not level up to the scientific concepts proven and accepted. The students have very creative ways of explaining their observations, mostly without scientific evidence. Other than preconcept, school-made inaccurate delivery of content is another reason for the alternative framework that exists in learning chemistry. This happens when a subject matter turns macroscopic to microscopic and symbolic, due to the inability of teachers to deliver the content the way it is intended due to their intricacy. The school made inaccurate delivery of content when questions were unanswered and problems were unsolved for the students to achieve deep understanding. [8] suggests that students' concepts and scientific language play a vital role in the existence of alternative frameworks in the students' minds. The new knowledge or scientific concept is built as a schema in the students' minds when the learning process happens. The knowledge framework is often built in a language dominant to the students, mostly their native language [12]. During the application of the scientific concepts, the knowledge in the students' minds, together with the prior knowledge, was channeled into the language that serves as the medium of instruction. For instance, the Chinese students might understand the scientific concepts in Chinese, but when the knowledge is put into words in Malay, it might differ from the original context or give rise to an inaccurate meaning.

Alternative frameworks present in high school students' mind particularly in chemistry, are known to exist even when they have proceeded to their tertiary education [13]. If the alternative framework is left unidentified and not corrected, it will always linger in the students' minds and hinder their ability to have a proper understanding of the scientific concepts. Having a deep understanding of chemistry or scientific knowledge is the key to producing a generation with critical thinking and problem-solving abilities that can contribute to the development of the nation by contributing to innovations and inventions.

2 PROBLEM STATEMENT

The contributing factors that acts as the root cause for the inaccurate conceptualization of the scientific concepts are the presence of alternative framework in learning Chemistry amongst students [14]. The existence of alternative framework in learning Chemistry begins from the school, meaning stemming in the primary school environment itself. This school made alternative framework could remain in the minds of students' until even tertiary education if it is not identified and rectified at school levels [13] The alternative framework could hinder the students from attaining deep understanding of Chemistry concept. The students could not attain meaningful learning if the misconceptions are not altered in an apt manner. Alternative framework of students restricts the application of scientific concepts in a real life situation and inability to enhance the critical thinking skills, creative thinking skills, problem solving skills and decision making skills [15] This also contributes to incapability of students to innovate and generate new ideas to produce new technologies in the near future.

Hence, identifying the alternative framework of students in Chemistry is of utmost importance to promote meaningful learning among students [16]. This research aims to identify the alternative framework in the topic Electrochemistry among secondary school students in Kluang, Johor in the first phase and develop an instructional module to be used by the teachers as an instructional aid addressing

the alternative framework of students in the second phase of the research. The findings of the first phase is reported in this paper.

3 RESEARCH OBJECTIVES

In this first phase of the study the conceptualisation of the students in electrochemistry were measured.

The objectives of this research includes:

1. To study the conceptualization level of scientific concepts of students on the concept electrochemistry.
2. To analyse the alternative frameworks that exist among students' understanding in electrochemistry.

4 METHODOLOGY

This research is aimed to identify the alternative framework of students in the topic electrochemistry in the first phase of the research and to develop an instructional module based on five phase Needham constructivist model and study the effectiveness of the module in overcoming the alternative framework of the students in schools. The samples were secondary school chemistry students from six schools in Kluang district, in the state Johor, Malaysia. The number of respondents in the first phase was 217. The research method used in this study is quantitative method. The data collected are in terms of survey. The paper and pencil test used as the instrument for the survey of scientific conceptualization of the secondary school students in Kluang district. The test consisted of open ended questions. The percentage and mean scores and standard deviations were calculated using SPSS version 20.0. Descriptive statistics were used to describe the conceptualization of scientific concepts of respondents on the concept electrochemistry. The students' responses were analysed to determine the alternative frameworks present in the samples in this study.

5 FINDINGS OF THE RESEARCH

5.1 Research Question 1

What is the level of conceptualization of scientific concepts of students in electrochemistry?

Table 1. The conceptualisation of scientific concept in electrochemistry

Test Scores	N	Minimum	Maximum	Mean	Standard Deviation	The Conceptualization of Scientific Concept in Electrochemistry
	217	1	89	47.2350	16.20314	Poor

The findings of the first phase of the research indicate that the conceptualization of electrochemistry by students is poor. This is indicated by the students' achievement in the electrochemistry test, which consists of six open-ended questions. This electrochemistry test evaluates the scientific concepts of the respondents.

Table 1 shows the conceptualization of the concept of electrochemistry by students. Table 1 shows that the minimum test score was one and the maximum test score obtained by the students was 89. The mean value for the distribution of the test scores is 47.23. The standard deviation computed from the distribution of test scores is 16.20. The value of the standard deviation is low, indicating that the deviation of the test scores from the mean value is less. This shows that most of the students' test scores do not deviate much from the mean value and are close to the mean value. From the mean value and the standard deviation computed, it can be understood that the conceptualization of the scientific concepts in the topic of electrochemistry is poor. These findings are in accordance with the previous research by [17], [18], and [6], which states that electrochemistry is an abstract concept at the microscopic level, and students understanding is hampered mainly due to the presence of an alternative framework.

5.2 Research Question 2

What are the alternative frameworks that exist among students' understanding in Electrochemistry?

Table 2. Analysis of the students' responses

Construct	Percentage (%) N = 217					
	Non Electrolyte	Molten (Electrolyte)	Negative Terminal	Positive Terminal	Electron Flow	Redox Reaction
	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6
1. Scientific concept	33	25	30	29	32	21
2. Alternative conceptual framework	58	66	63	61	61	64
3. No response	4	2	5	6	4	10
4. Other responses	5	4	2	4	3	5

From Table 2, it can be concluded that every question has a higher percentage of an alternative framework compared to the accurate understanding of the actual scientific concept tested in the items. Each question indicates that more than half of the sample (N = 217) exhibits an alternative framework in their responses. The percentage of alternative frameworks for question 1 is 58%, or 124 students. As for question 2, the percentage of students who mastered the scientific concept is 25%, whereas the percentage of students with alternative frameworks amounts up to 66%, or a total of 147 students. This indicates the students have a very poor understanding of the tested scientific concept. For question 3, the percentage of students who have mastered the scientific concept is 30%, whereas the percentage of students who have an alternative framework is 63%. The percentage of students who understood the scientific concept in question 4 is 29%, whereas with alternative framework is 61%. For question 5, the number of students who have an alternative framework is 134, which amounts to 61%, and those who have mastered the scientific concepts are 32%. For question 6, the number of students who have mastered the scientific concept is 21%, whereas the percentage of students with inaccurate scientific concepts is 64%, or 138 students. The alternative framework for each question was analyzed and tabulated as in Table 3.

Table 3. Alternative framework present for concepts in electrochemistry among students

Students Response for Non-Electrolyte	Number of Samples (N = 217)	Percentage (%)
Alternative framework		
i. Solid ionic substance is a nonmetal substance	30	14
ii. Atomic structure in solid cannot conduct electricity	21	10
iii. Solid ionic substance do not have ions	21	10
iv. Solid ionic substance is made up of metal and nonmetal element, thus do not conduct electricity	19	9
v. Electricity unable to pass through ionic substances	6	3
vi. Solid ionic substances do not contain ions	11	5
vii. Electric charge could not pass through solid ionic substance as it consists of closely arranged particles	16	7
Students Response for Molten (Electrolyte)		
Alternative framework		
i. Molten NaCl does not conduct electricity because it's in solid state	44	20
ii. Molten NaCl do not contain charged particles	35	16
iii. Molten NaCl is an insulator thus do not conduct electricity	20	9
iv. NaCl is in metallic group in the periodic table thus conduct electricity	13	6
v. Molten NaCl is attracted by a strong electrostatic force, thus conduct electricity	18	8
vi. NaCl is a reactive metal	14	6
vii. NaCl is a covalent compound as it conducts electricity	3	1
Students Response for Negative Terminal		
Alternative framework		
i. Magnesium is placed lower than copper in electronegativity series	47	22
ii. Copper is the negative terminal because placed lower than Magnesium	41	19
iii. Copper is more electropositive than Magnesium	30	14
iv. Copper plate act as cathode	18	8
Students Response for Positive Terminal		
Alternative framework		
i. Copper is placed higher than Magnesium	51	23
ii. Copper is the positive terminal because placed higher than Magnesium	32	15
iii. Magnesium is less electropositive than copper	26	12
iv. Magnesium plate act as anode	24	11
Students Response for Electron Flow		
Alternative framework		
i. The electrons move from positive terminal to negative terminal	53	24
ii. Copper serves as the anode and magnesium acts as the cathode	39	18
iii. A more electronegative metal will release electrons	27	12
iv. Magnesium ions move to the copper plate	15	7

(Continued)

Table 3. Alternative framework present for concepts in electrochemistry among students *(Continued)*

Students Response for Redox Reaction	Number of Samples (N = 217)	Percentage (%)
Alternative framework		
i. Copper donates 2 electrons to achieve stable octet	38	18
ii. The magnesium atom will be discharged to become Magnesium ion, Mg2+	35	16
iii. $Cu \rightarrow Cu^{2+} + 2e^-$	27	12
iv. $2H^+ + 2e^- \rightarrow H_2$	26	12
v. OH^- or hydroxyl ion is selectively discharged	12	6

6 DISCUSSION

The analysis of the students' responses indicates a devastating level of alternative framework being present in the students' understanding of the concept. The highest percentage by comparison of students who have an alternative framework is for question 2, which accounts for 66% out of 217 students. This is followed by question 6, which accounts for 64% of students having an alternative framework, followed by question 3, which is 63%, the slightly lower percentage for questions 4 and 5, which are 61%, and question 1 which has a percentage of 58% of students having an alternative framework in the topic electrochemistry. For the analysis of the students' responses, more than half of the 217 students who sat for the electrochemistry test have an alternative framework in electrochemistry.

The findings of this study add to the existing literature and provides alternative framework for the concept of electrochemistry. The preconcept is defined as the prior knowledge or idea that lingers in the knowledge schemata of the students' minds before the learning process happens. The preconcept regarding a topic is formed through the students' individual experiences, knowledge, and exposure to information, as well as their beliefs and way of thinking. The preconcept plays a major role in the conceptualization of the proper scientific concept in the minds of the students. Students' learning can be optimized when they can connect what they are learning to what they already know. In the situation where prior knowledge is activated and sufficient, the learning happens in an intended manner, and a good foundation of knowledge is built.

In electrochemistry, many preconcepts are learned from a basic level among the students, from the lower form until the upper form. Inaccurate prior knowledge regarding a scientific concept hinders the learning of the proper scientific concept. For instance, the students have prior knowledge that electrochemistry, as in a chemical cell, uses electricity. This is an inaccurate idea, as the chemical cell produces electricity due to the difference in potential between two different metal electrodes. This preconcept, if not identified and corrected, could lead to a poor understanding of the electron flow in the chemical cell and how the electrochemical cell works.

To establish a proper understanding of electrochemistry, certain prerequisite concepts, namely chemical substance, the concept of oxidation states, and balancing chemical equations, also have to be mastered [6]. In order to learn this topic, the students have to master the oxidation and reduction concepts to further understand the process that happens in the electrodes of the electrochemical cell. The inability of the students to recall this scientific knowledge hinders their ability to learn the electrochemical cell in a prompt manner. Due to this, the students are not able to

write the half-cell equation to represent the oxidation and reduction processes that happen in the positive and negative terminals of the chemical cell. Besides that, the students also have difficulties writing the chemical equation, unable to represent the chemical reactions happening in the cell. This shows that students have problems representing scientific knowledge on a symbolic level.

This study is expected to provide guidance to educators in Malaysia to aid in the proper conceptualization of scientific concepts in electrochemistry. This will definitely contribute to the improvement of scientific literacy among Malaysians.

7 FURTHER RESEARCH RECOMMENDATIONS

The study, upon conducting the research, advocated a few recommendations that can be taken into consideration for the success of upcoming research. The insights from this study are expected to improve the next upcoming research. Further recommendations are listed below:

1. The research respondents, the students have very limited time to be spent for answering the electrochemistry diagnostic test. The respondents have ample commitments and they are often in the rush of time to balance their education and extra co-curricular activities. The researcher faced some difficulties when some respondents were reluctant to spend their time to be involved in this study. The researcher recommends the instruments to be in Google Forms or any other online means where students are able to answer any time in the given time frame by using smartphones, tablets, or Internet-connected mobile devices. This eases the data collection process as it is undeniable that today's learners have become more tech-savvy, and prefers mobile technologies as their learning preferences [19].
2. The respondents to this study are sufficient for the results to be generalized to the student populations in Johor State, Malaysia. The researcher would recommend more respondents were involved throughout all the states in Malaysia by incorporating smartphones, tablets, or Internet-connected mobile devices in the data collection process to get a proper understanding of the alternative frameworks present among students in electrochemistry in Malaysia. Mobile technologies will definitely facilitate this process to get an accurate picture of the understanding of chemistry concepts among secondary school students in Malaysia. This is a crucial step towards fortifying scientific literacy in Malaysian society.
3. The findings of the first phase of this study are used to create an instructional module with a constructivist approach in the second phase of the research. The researcher recommends that the instructional module be an online module that is accessible using any mobile phone or electronic device. Online instructional modules enable the teachers to easily identify students' alternative frameworks and serve as guidance for teachers in choosing the proper teaching strategies and teaching aids for an active learning environment [20].

8 CONCLUSION

This research is conducted with the hope that it can identify the alternative framework that exists among students in the topic of electrochemistry which is often considered difficult by the students. Hence, this research is hoped to guide

the chemistry teachers to be progressive and proactive teachers in the classroom to eliminate the thought that chemistry is difficult among the students. The discussions and recommendations made in this study are intended to steer the chemistry education world to a higher level in the Malaysian education system. It is a paramount effort to improve the quality of chemistry education by strengthening the scientific conceptualization to create a scientific society capable of making decisions and solving problems by applying the scientific knowledge learned in a daily-life context.

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