Difficulties to Master Scientific Literacy Competencies Among Secondary School Students

Lavaniya Chelvan, Johari Surif, Nor Hasniza Ibrahim

Abstract:Scientific literacy is one of the 21st-century skills that are important to develop students to face the challenges in this era of globalization. Therefore, this study aimed to investigate and identify the difficulties encountered by students to master scientific literacy competencies. The scientific literacy competencies are to explain phenomena scientifically, evaluate and design scientific inquiry and to interpret data and evidence scientifically. Sceintific Literacy Assessment and Thinking Aloud Protocol were used in this study. A total of 40 form four science stream secondary school students were selected using random sampling method following with six respondents selected to be interviewed. The instrument used include the scientific literacy assessment together with semi-structured interview questions. Answers of Scientific Literacy Assessment were analysed by using descriptive statistic involves frequency and percentage. Where else, interview transcripts from Thinking Aloud Protocol were analysed by using content analysis. The findings showed students find difficulties in explaining the phenomena scientifically the most. Findings of this study could help teachers and students to improvise the teaching and learning of chemistry to be more effective.

Index terms: Scientific literacy, 21st-century skills, explaining the phenomena scientifically,evaluate and design scientific inquiry, interpret data and evidence scientificallysecondary school

I. INTRODUCTION

Science and Technology is one of the fundamental requirements in this 'knowledge era' or 'k-economy' which eventually contributes to the economic development of the country based on intellectual capital. Therefore, the education system plays an important role to produce the scientifically intellectual community in Malaysia for achieving the aforementioned goals for the betterment of the country.Malaysian Ministry of Education (MOE) has developed the Secondary School Standard Curriculum (SSSC). This Curriculum provides the better basis for secondary schooling science programs. It is mainly designed to develop students with scientific knowledge and skills incorporated with social values and positive attitudes towards the learning of Science in ensuring their competitiveness in the globalization area.

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One of the primary considerations in the SSSC is to develop a highly intellectual holistic individual who is scientifical with technologically knowledgeable and capable of thinking creatively to solve problems in this 21st-century environment. Therefore, 21st-century skills are important and integrated into Secondary School Standard Curriculum (SSSC). Based on Osman *et al.*(2010), one of the important elements in 21st-century skills is scientific literacy.

Scientific literacy helps students to develop the understanding of science concepts and applying them in current issue by making own decision to solve the problem efficiently and set up discussion with the community by using technology to solve the problem.

A scientifically literate person is someone who has the competencies to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically.These are the scientific literacy competencies that are essential to be mastered by each of our students. Therefore, the process of teaching-learning should be able to elicit the scientific literacy competencies among students. Scientific literacy competencies are important for understanding science concepts and processes needed for personal decision making, involvement in scientific issues and economic productivity Thus, it is clearly stated that scientific literacy competencies consist of important skills that develop students for science learning scenarios of the 21st century and also creating citizens for future generations.

Scientific Literacy Competencies

Based on OECD (2016), Scientific literacy has been defined as the ability to cope up with science-related issues and having the mind with full ideas of science. This competency requires content knowledge, procedural knowledge, and epistemic knowledge.

A scientifically literate person is believed to show all the scientific literacy competencies such as explaining phenomena scientifically, evaluating and designing scientific enquiry, and interpreting data and evidence scientifically. Therefore, this study will be a focus on scientific literacy competencies. The description of each competency is below.

a) **Explain Phenomena Scientifically**: Explain a phenomenon scientifically is the ability of students to recall and apply the theories, information, and scientific knowledge for any situations. It is all about interpreting and explaining the phenomenon of interests by predicts possible changes as well as justifying the predictions with relevant information. In other words, it is also the ability to offer explanatory hypotheses.

b) **Evaluate and Design Scientific Inquiry:**Evaluate and design scientific inquiry is the ability to evaluate scientific

investigations based on reports and findings. This competency requires Procedural and Epistemic knowledge. Students should be able to come out with the scientific questions to be investigated. This competency needs knowledge of the aspects of a scientific investigation. Students should be able to identify the importance of previous researches to make judgemental on specific scientific enquiry.

c) **Interpret Data and Evidence Scientifically**: Interpret data and evidence scientifically is the ability to analyses and evaluates scientific evidence in their own representations. This competency requires content knowledge, procedural knowledge, and epistemic knowledge. Students should be able to analyse the particular data, summaries it and eventually draw conclusions by using other own representations. In a nutshell, this competency helps students to understand the connection between evidences and conclusions.

The Limitations To Develop Scientific Literacy Competencies Among Students

Scientific literacy is one of the important skills in Science education in current globalised world. Based on the framework provided by OECD (2016), scientific literacy is the ability to identify science related real-life issues by using the knowledge from the science ideas as a reflective citizen that require the mastery of scientific literacy competencies which are the ability to explain phenomena scientifically, to evaluate and design scientific inquiry, and to interpret data and evidence scientifically. Moreover, mastering scientific literacy competencies make students to improve their problem-solving ability in their real-life issues by thinking scientifically with the use of various research tools wisely . Therefore, mastering scientific literacy competencies could benefit every aspect of lives to be better[1]-[5].

However, based on several studies discussed below, there are many factors contribute to the difficulties for students to develop scientific literacy competencies especially in chemistry. The limitations are rooted in the inability of students to develop ideas and skills to solve authentic scientific issues that need to be identified for further development of scientific literacy competencies[6].

Most schools are still practicing on teaching the fix facts of Chemistry without encouraging students to make judgemental whether it is right or wrong, that will lead to difficulties in fostering problem-solving skills . Enhancing students' content knowledge only does not harness their skills to develop ideas and skills to make effective scientific decisions[7].

Traditional teaching strategy could be one of the factors contributing to the limitations for our students to master the art of creating and investigating scientific questions.Traditional teaching strategy is scarcely teaching the students to be creative, cross-disciplinary problem identification and problem-solving skills . This strategy is only highlighting the process of acquiring facts and basic science process which solely depending on the teachers. Despite all the initiatives in the Malaysian Education system, teacher-centered teaching practices still taking lead in the classroom learning. Sometimes, there are teachers who are more prone in providing the knowledge directly to students without asking introduction questions to develop critical thinking of students to find their own learning path. This way, students are not able to develop their thinking skill when everything is provided to them[8]-[10].

Furthermore, most of the education systems are more on examination-based where teachers are rushed to complete the syllabuses within the stipulated time before students sit for major national examinations . Therefore, most of the teaching strategies in school are based on textbooks where the contents will be asked in the major national examinations and usually teacher oriented. Usage of textbooks solely usually do not provide the sufficient practical knowledge for students to be used practically in their daily life which eventually did not promote the development of scientific literacy competencies (Sukor *et al.*, 2010).

Moreover, due to the education framework that is more on highlighting teaching and learning that leads to a more individual work then collaborative works. Students are less exposed to collaboration work and this is not developing their social skills. Therefore, a detailed framework needed to be implemented to make students to collaboratively share their ideas for solving a problem which eventually contributes to the development of scientific literacy competencies.

II. RESEARCH OBJECTIVES

The aim of this study is to :

Identify the difficulties encountered by students to explain phenomena scientifically, evaluate and design scientific inquiry and to interpret data and evidence scientifically.

III. RESEARCH QUESTIONS

In order to achieve the objective that has been mentioned above, the research question below has been used as a guide:

What are the difficulties encountered by form 4 chemistry students to explain phenomena scientifically, evaluate and design scientific inquiry and to interpret data and evidence scientifically?

IV. RESEARCH METHODOLOGY

Research Design

This study involved qualitative research in think-aloud protocol. Based on Cooke (2010), think aloud protocol is very useful to get the respondents' perception during their process of doing a task. It could be done during a test or any assessments related to the topic that we would like to know the thoughts of the students.

Sample and Population

The population in this research were a total of forty secondary form four science stream students have been selected as respondents to answer the Scientific Literacy Assessment.Based on the outcomes of the Scientific

Assessment, a total of 6 students have been chosen to be interviewed in order to find the difficulties to answer the questions in terms of to explain the phenomena scientifically, to evaluate and design scientific enquiry, and to interpret data and evidence scientifically.Sampling technique that has been used for Phase I and II was through purposeful sampling approach. Purposeful sampling is used for getting information in a more depth manner from students who are knowledgeable in the issues of the study .[11]-[12]

Instrumentation

The instrumentations being used are Scientific Literacy Assessment together with semi-structured interview questions to find the difficulties encountered by students to explain the phenomena scientifically, to evaluate and design scientific enquiry, and interpret data and evidence scientifically.The questions in the Scientific Assessment are from PISA Science Assessment that arecategorised based on the scientific literacy competencies. One question for each competency resulting in a total of three questions has been included in this Scientific Assessment.

Validity and reliability of the Research Instruments

Face validity for the instruments has been done by giving the Scientific Assessment to sample of students who are learning chemistry in Form 4 follow with the interviews with the students to make sure the real respondents will understand the test questions in the instrument later in the study. Amendment has been done based on the suggestions and response that have been given by the sample students. Moreover, the content validity has been checked by three experience chemistry teachers to make sure the content is aligned with the objective of the study and the level of the respondents.

Pilot Study

According to Van Teijlingen and Hundley (2002), a pilot study is a pre-testing of a research instrument for any amendments or improvements before large-scale study been conducted. Referring to the reasons above, a pilot study has been carried out to test and modify the test instruments that will be used before conducting the real research. A total of 10 form four science stream students from a school in Johor, Malaysia have been chosen to take part in the pilot study.

V. FINDINGS

Findingsis to report the results of the qualitative data to discuss the difficulties encountered by form 4 chemistry students to explain phenomena scientifically, evaluate and design scientific inquiry and to interpret data and evidence scientifically.

The answers given in Sceintific Literacy Assessment have been analysed using descriptive statistic involves frequency and percentage. The result as below:

Table 1: Percentage Distribution of Students Obtained Full Credit (complete answer)

Scientific Literacy Competencies	**The average percentage of students who obtained full credit (%)**
Explain Phenomena Scientifically	
Question 1(a)	60
Question 1(b)	32.5
Question 1(c)	15
Evaluate and Design Scientific Inquiry	
Question 2	52.5
Interpret Data and Evidence Scientifically	
Question 3 (a)	31
Question 3 (b)	31
Question 3 (c)	30
Question 3 (d)	40

Based on the summary above, there are only two questions that students were able to obtain above average level (50%) where else the other questions are below the average level (50%) and considered not satisfactory. The questions that students were able to achieve an above-average level (50%) are Question 1(a) and Question 2. This shows students have difficulties in answering questions that needs written explanation with reklevant evidences.

Where else, the data from thinking aloud protocol which are the interview transcripts have been analysed using content analysis method based on Strauss and Corbin (1990) which consists of three processes which are open coding, axial coding and selective coding. The result of the analysis as below:

Table 2: Categories Indentified in Axial Coding

Category	**Details**
Scientific writing	- Communicating ideas, finding and activities to others by providing relevant evidence.
Graph interpretation	- Ability to make use of any forms of scientific data and evidence to make conclusions and claims.
Designing scientific enquiry	- Ability to evaluate and analyse reports of scientific findings and investigations analytically.

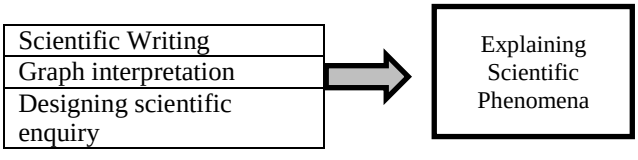

Figure 1: Core Category Identified From the Categories

Based on the data obtained through content analysis of the interview transcrips, it can be concluded that

there are three learning difficulties experienced by respondents during the process of answering the scientific literacy assessment. There are scientific writing, graph interpretation and designing scientific enquiry. The core category that has been identified is Explaining Phenomena Scientifically. All the three learning difficulties are actually contributing to the difficulty to explain phenomena scientifically as shown in Figure 1.

VI. CONCLUSIONS

The study shows 64% of the total 40 respondents faced difficulties to explain phenomena scientifically. Their explanations were not complete with the relevant evidence needed and based on the interview transcripts; they faced difficulties in scientific writing. Moreover, the students could not include relevant words to construct scientific sentences as answers.

This is because students did not know the correct vocabularies to be used in writing their answers. Students claimed that they were in shortage of words to write their answers as they did not understand the phenomena given. The phenomena were something new for them and did not have broad knowledge about it. They were not exposed to real-life contexts that are needed for answering the scientific literacy questions.

These limitations can be overcome by implementing effective teaching strategies that could provide students be exposed to various contexts. This way, students could master knowledge from different divisions at a time and this will be very helpful in their scientific explanation. Moreover, students' learning process should be incorporated into activities that require them to research deeper for them to know different scientific vocabularies related to the specific science concepts.

The findings obtained through this study also give ideas to improvise the methods of assessments in science education, especially in chemistry. The finding that shows students are very poor in writing scientifically which lead to the poor ability to explain phenomena scientifically gives an insight that assessment structure can be improved by applying few changes as below:

1. Teachers can prepare more open-ended questions rather than objective questions to develop students thinking skills and at the same time develop their writing skills. This is because open-ended questions need students to explain the particular scientific phenomena and their explanation deeper based on their understanding.
2. Open-ended questions also can be designed in a way where require students to provide answers with relevant evidence. This way, students will do revisions by not only memorizing the facts but also learning the general knowledge about current scientific issues for supporting their explanation for the answer.
3. The open-ended question needs to be designed with a purpose to evaluate students' own understanding of the particular topic being asked. Apart from only evaluating understanding of the scientific facts that they could have memorized, students also need to be exposed with questions on writing their opinion for the current scientific problems. This way, students will be more vigilant about what's happening around them and could provide their own creative solutions for any global issues.

Apart from that, Chemistry curriculum should be able to cater learning syllabus that could lead in improvising the scientific writing skills of students. The education system should not focus only one particular context when teaching the students but integrate multiple contexts. This way, students could learn many things at one time.

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