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High School Science Students' Difficulties In Constructing Scientific Explanations In Biology

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Abstract

The goals of science classrooms are to help students become scientifically literate citizens and to encourage greater public understanding in a science-and-technology-infused world. To be scientific literate citizens, especially in the 21st century era, students need to be able to evaluate evidence and reasoning presented in e-magazine, news, or articles. In addition, students should be able to write their own scientific explanations with appropriate claims and reasoning to articulate and convince others. Especially for science stream students, constructing scientific explanations becomes an essential practice to scientific inquiry. This study investigated high school science students in constructing their scientific inquiry using an open-ended test. The students were provided with the test items containing data about energy flow in different ecosystems, and were asked to write scientific explanations using evidence from the given data to support their explanation with relevant scientific reasoning that they have learned in their biology classroom. There were 72 students, 29 female and 43 male, from two science grade 10 classrooms involved in this study. The finding suggested that students faced difficulties in constructing scientific explanations in two issues. Firstly, the students could not provide appropriate and sufficient evidence to support their claims. Secondly, they did not support their claims with scientific reasoning, but they often used their opinions to support the claims. The results revealed that in order to succeed in enhancing students' scientific explanation practice, the science classrooms should support students in the use of evidence and reasoning effectively.

1. Introduction

Scientific explanation is defined as one of the essential practices in science education and served as fundamental knowledge and skills in scientific inquiry [1]. Students engaging in scientific explanation not only promote their understanding of science, but also the nature of science [2]. Since scientific knowledge is an explanation of natural phenomena acquired by scientists using evidence they explored, and supporting with scientific reasoning [3]. There are three components of good scientific explanation including claim, evidence, and scientific reasoning; also the explanation should provide enough valid evidence and reasoning to support the precise claim [4]. Not only in science, scientific explanation could be adapted across a variety of contexts. In rapid growth of information technology, people should be able to criticize whether the claims presented in news, articles, fact sheets, or magazine are well supported with reliable evidence and reasoning [5]. Thus, scientific explanation could be claimed as an essential knowledge and skill for 21st century era citizens. In science learning, students should be able to (i) give priority to evidence when developing or evaluating scientific explanations, (ii) formulate scientific explanations from evidence to address scientifically oriented questions, (iii) formulate and revise scientific explanations using logic and evidence, and (iv) have a clear understanding that scientific explanations emphasize evidence [6]. Although engaging scientific explanations is an important learning goal for students, they often have difficulty constructing and connecting their claim and evidence [7]. In Thailand, Basic Education Core Curriculum states that high school students should be able to explain the results of an investigation based on evidence and support with scientific reasons, use evidence and conduct research to collect more evidence in order to accept or reject existing knowledge or idea.

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Even though the scientific explanation is an explicit goal in science learning, high school students in science stream, where the researcher teaches biology at, are always missing the evidence and reasoning when they constructed an explanation. There were several research studies in biology science classroom engaging in investigating students' conceptual understanding and skills [8], but rarely research studies have done in identifying students' scientific explanation. In this inquiry, how well high school students construct scientific explanations in biology, and which component of scientific explanation is the most challenging were provided.

2. Research approach and methodology

2.1 Participants

The participants were 72 tenth-graders who are in a science stream and had studied ecosystem topic in the first semester of 2016. They were 29 female and 43 male students from a high school in Phrae province (northern Thailand).

2.2 Data collection

The research instrument used in this study was an open-ended written test constructed by the researchers, and evaluated by three experts. All comments given by experts were used to edit the item's prompts. The Index of item objective congruence (IOC) of all items was 1.0. The test includes 10 open-ended questions asking the students to write scientific explanations about energy flow in different ecosystems using evidence from the given data to support their explanation with relevant scientific reasoning.

3. Data analysis

Each response was analyzed through three components of scientific explanation; which are, (i) claim: an answer to a given question. (ii) evidence: data that helps to construct, support and defend a claim, and (iii) reasoning: a statement given to justify claims showing how evidence could be used to support claims that connect to science concept. The specific rubric of each question was developed based on the work of McNeill, et al [9], who identified each component of scientific explanation. Each component was categorized into three levels; 0, 1, and 2. Each student's response was coded and categorized then placed in each rubric level.

4. Research findings

The findings from the students' performance were shown in each component of scientific explanation, as follows.

Table 1. Students' ability in constructing scientific explanation related to the concepts of energy flow.

Score	Criteria	Number of student (percent)
Claim: A conclusion that answers the question.		
2	Makes an accurate and complete claim	50 (69.4)
1	Makes an accurate but incomplete claim	20 (27.8)
0	Does not make a claim, or make an inaccurate claim	2 (2.8)

Table 1. Students' ability in constructing scientific explanation related to the concepts of energy flow. (cont.)

Score	Criteria	Number of students (percent)
Evidence: Appropriate scientific data that supports the claim.		
2	Provides appropriate and sufficient evidence to support claim.	19 (26.4)
1	Provides appropriate, but insufficient evidence to support claim.	23 (31.9)
0	Does not provide reasoning or only provides reasoning that does not link evidence to claim.	30 (41.7)
Reasoning: A justification that links the claim and evidence.		
2	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principle	6 (8.3)
1	Provides reasoning that links the claims and evidence.	7 (9.7)
0	Does not provides reasoning or only provides reasoning that does not link evidence to claim	59 (82.0)

5. Conclusion and discussions

The findings suggest that the majority of the students; 70%, could make an accurate and complete claim. However, most of the students faced difficulties in supporting the claims with evidence; only about 19% could provide appropriate and sufficient evidence to support their claims. Scientific reasoning was the most challenging component in writing scientific explanation for the students; most of them, 82%, could not provide reasoning that indicates connection between evidence and claim. In general, most of the students could not write a good scientific explanation; agreeing with the previous research study [10]. The study also found that the students often used their previous experience or opinions to support their claims without using the evidence given in the prompt. The results of this study indicated that science classrooms need to emphasize more on scaffolding students in the use of appropriate and supportive evidence as well as scientific reasoning when making conclusion from their investigations or even readings in order to enhance students' scientific explanation practice.

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