Effectiveness of the use of question-driven levels of inquiry based instruction (QD-LOIBI) assisted visual multimedia supported teaching material on enhancing scientific explanation ability senior high school students

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Abstract. In this study, the effectiveness of the use of Question-Driven Levels of Inquiry Based Instruction (QD-LOIBI) assisted visual multimedia supported teaching materials on enhancing senior high school students scientific explanation ability has been studied. QD-LOIBI was designed by following five-levels of inquiry proposed by Wenning. Visual multimedia used in teaching materials included image (photo), virtual simulation and video phenomena. QD-LOIBI assisted teaching materials supported by visual multimedia were tried out on senior high school students at one high school in one district in West Java. A quasi-experiment method with design one experiment group (n = 31) and one control group (n = 32) were used. Experimental group were given QD-LOIBI assisted teaching material supported by visual multimedia, whereas the control group were given QD-LOIBI assisted teaching materials not supported visual multimedia. Data on the ability of scientific explanation in both groups were collected by scientific explanation ability test in essay form concerning kinetic gas theory concept. The results showed that the number of students in the experimental class that has increased the category and quality of scientific explanation is greater than in the control class. These results indicate that the use of multimedia supported instructional materials developed for implementation of QD-LOIBI can improve students’ ability to provide explanations supported by scientific evidence gained from practicum activities and applicable concepts, laws, principles or theories.

1. Introduction

Scientific explanation is one of the ability that must be possessed by students after following physics learning. In the PISA 2015 framework, scientific explanation is part of the competence domain of scientific literacy. In PISA 2015 framework mentioned that one part of the competence domain of scientific literacy is explain phenomenon scientifically. Explaining scientific phenomena, however, requires more than the ability to recall and use theories, explanatory ideas, information, and facts (content knowledge). Offering scientific explanation also requires an understanding of how such knowledge has been derived and the level of confidence we might hold about any scientific claims. For this competency, the individual requires a knowledge of the standard forms and procedures used in
scientific enquiry to obtain such knowledge (procedural knowledge) and an understanding of their role and function in justifying the knowledge produced by science (epistemic knowledge).

Forms of scientific explanation formulated by scientists around certain phenomena are limited by their investigation questions. In general, scientific explanation framed in the investigation process begins with a particular question [1]. Thus the scientific explanation was an answer of the investigation question and it has an epistemic important relation. Evaluation to assess the scientific explanation with regard to the value in answer to the question of the investigation, even when a new explanation is generated based on the question, they were still trying to answer the questions which posed by scientist [2].

Martin has analyzed the complexity of the field, by identifying five meanings for the concept of explanation in science and science education: a clarification of what a phrase means in a scientific context; a justification for some belief or action; a causal account of an event or process; a citation of a theory from which a law may be deduced; an attribution of function to an object [3]. Given the multiple meanings of the term, the literature reports some efforts to develop a typology of scientific explanations, which are based on the different functions that explanations serve in different contexts. Table 1 provides a typology of scientific explanations and some of their characteristics, as constructed by Norris et al. [4].

| Types of explanation          | Characteristics                                      |
|------------------------------|------------------------------------------------------|
| Interpretive explanation     | clarifies meaning / defines terms, propositions, treatises |
| Justificatory explanation    | explains by justifying why something was done / provides reasons for acting |
| Descriptive explanation      | explains by describing a process or structure        |
| Causal explanation           | explains by citing a cause for events or laws        |
| Deductive- nomological explanation | explains particular facts or general laws by deriving the facts or laws from general laws and other facts |
| Statistical explanation      | explains facts by showing them to be highly probable/ basic structure is an inductive argument |
| Functional explanation       | explains a fact by indicating its function           |
| Explanatory unification      | explains phenomena by fitting them into a general worldview/aims to derive largest number of facts from smallest number of assumptions |
| Pragmatic explanation        | explains by answering why questions / questions are asked and answers are given in a context |
| Narrative explanation        | explains an event by narrating the events leading up to its occurrence / posits some events as causes of others |

Scientific explanation is closely related to scientific inquiry activities. Scientific investigation is conducted to develop an understanding of the nature of science by conducting investigations [5]. Scientific inquiry refers to the procedures used by scientists to study natural phenomena and to make explanations based on evidence obtained through the investigations. White and Frederikson stated that scientific inquiry was defined as the process of asking questions, generalizing the data based on experimental results and systematic observation [1]. Scientific inquiry was often described as the process of building knowledge through various plausible explanation that fits the data. This explanation then presented in a peer community to be criticized, debated and corrected [2, 6]. Thus the inquiry based science learning involves argumentation as a very important part of communication skills for support [7]. Enduran stated that the arguments supporting the enculturation into practice the scientific culture and to develop epistemic criteria for evaluating knowledge and supporting the development of
reasoning, in particular in the election theory or attitude determination based on rational criteria [8]. Implementation of the argument as a learning strategy determines the epistemic aspects of the investigation more explicit can improve students' ability to investigate and to support the development of their epistemological [9]. Thus the argument process plays an important role in exercising scientific inquiry skills.

To build scientific explanation ability of students through physics learning can be done by applying learning using inquiry method. Pedagogical context placing inquiry as a series of instructional activities that put students involved in activities to develop their knowledge and use scientific ways of working to find an explanation of natural phenomena based on an investigation to gather scientific evidence [10].

Unfortunately for the students who are not familiar with the investigation activities, the application of inquiry method is not always easy. One of the instruction that involves gradual inquiry process in it is level based inquiry (LoI) based learning popularized by Wenning [11]. Level of inquiry based instruction consists of five learning stages: 1) discovery learning, 2) interactive demonstration, 3) inquiry lesson, 4) lab inquiry, 5) Real-World Application, and 6) hypothetical inquiry.

For the implementation of levels of inquiry based instruction (LOIBI), it is necessary to support teaching materials, whether in the form of worksheets, collection of phenomena, problem sheets, note of the essential material, PPT slides, and others. Physics studies macroscopic and microscopic phenomena. Macroscopic phenomena include quantities that can be observed and measured, whereas microscopic phenomena include quantities that cannot be observed with the eye and cannot be measured. Because of its invisible nature, the discussion of microscopic phenomena is often confronted with difficulties. The study of microscopic phenomena done only by a verbal approach often leads to misunderstanding and misconception, because they are forced to fantasize microscopic processes that occur from what they hear from the teacher.

It takes media that can visualize abstract and microscopic phenomena of physics. Learners will be able to more easily understand a phenomenon when they have the opportunity to be able to see the mechanisms or processes that occur in the observed phenomenon, even if they are only models or illustrations. The development of communication technology, computing and information has brought fresh air in science learning. Some of the features of this technology can be utilized as a tool that can be used to visualize a variety of abstract or microscopic phenomena that cannot be seen as an observable phenomenon. These features include: static image features including graphics and diagrams, video phenomenon features, animation features and virtual simulation and lab-virtual features. All of these features can be assembled in a visual multimedia class.

The research was conducted to explore the potential of application of Question Driven-Levels of Inquiry Based Instruction (QD-LOIBI) supported by teaching materials using visual multimedia in providing scientific explanation ability of high school students. This article describes the process and results of QD-LOIBI implementation in the learning of kinetic gas theory materials.

2. Method
The method used in this research is the quasi-experiment method with design one experiment group (n=31) and one control group (n=32). Experiment group were given QD-LOIBI assisted teaching material supported by visual multimedia, whereas the control group were given QD-LOIBI assisted teaching materials not supported visual multimedia as shown in Table 2.

| Group   | Pre-test | Treatment | Post-test |
|---------|----------|-----------|-----------|
| Experiment | O        | X₁        | O         |
| Control  | O        | X₂        | O         |

Here, O is a scientific explanation test concerning kinetic gas theory, X₁ is a treatment using QD-LOIBI assisted teaching material supported by visual multimedia and X₂ is a treatment using QD-LOIBI assisted teaching material not supported visual multimedia.
assisted teaching materials not supported visual multimedia. This experimental research was conducted at one senior high school in one district in West Java. The sample was chosen randomly. The instrument used for data scientific explanation ability is three test items in the form of open-ended questioner related to concept of gas kinetic theory.

To analyze the improvement of the category and quality of scientific explanation achieved by the students in both class, carried out the following analysis steps: the first step on the analysis of students’ scientific explanations involved their classification in terms of scientific reasoning content. For each one of the three items of the questionnaire, students’ responses were classified in four broad categories: a) Appropriate explanations: they include scientifically accepted ideas about the phenomena; b) Inappropriate explanations: they include student’s alternative ideas about phenomena; c) No explanations with justification: the students comment that they do not know and explain the reasons; d) No explanations: no explanation is given or the response is irrelevant to the question asked. Table 3 shows guidelines for encoding scientific explanation categories based on student responses to a given question.

| Question-1 Categories in terms of the content | Categories in terms of the quality | Description |
|-----------------------------------------------|-----------------------------------|-------------|
| Appropriate Explanations Category 3           | Containing law/principle AND the appropriate data AND the correct conclusion (AND the conditions) |
| Category 2                                   | Containing law/principle AND inefficient data AND correct conclusion OR law/principle AND correct conclusion OR appropriate data AND correct conclusion |
| Category 1                                   | Containing only the correct conclusion |
| Inappropriate explanations                    | Containing misconceptions |
| No explanation with justification             | The student stated that he/she does not know and explained the reasons |
| No explanation                               | No answer was given or the response was not referring to the question |

Then, attention was turned to the appropriate explanations, which were classified in terms of their quality (defined as the degree to which the information provided by the student is enough to back up the explanatory conclusion reached). As exemplified in the following lines of this section, the properties of this category varied, in relation to the different content of each item.

Yet, for all the items the categories that were formed involved the following: a) Category 3: It stands for the most complete appropriate explanations, where all the needed information is provided by the student to back up the explanatory conclusion reached; b) Category 2: It involves the cases where more information is needed to back up the explanatory conclusion; c) Category 1: It refers to appropriate explanations, where only the correct claim is provided by the students.

3. Result and Discussion
Based on the categories presented in the previous section, for each one of the items No.1 - No.3 of the open-ended questions, each student explanation was identified in terms the category which falls, as far
as the content is concerned. The overall number of students’ explanations fallen in each category for each item was counted, both in pre- and post-test. The results of the data analysis are presented in table 2. Table 4 shows the number of students’ explanations in each category in terms of the content for each item both in the pre- and post-test.

**Table 4.** The number of students’ explanations in each category in terms of the content, for each item, for experiment and control group in the pre – and post-test

| Categories in terms of the content | Group          | Question-1 |           | Question-2 |           | Question-3 |           |
|-----------------------------------|----------------|------------|-----------|------------|-----------|------------|-----------|
|                                   |                | Pretest    | Posttest  | Pretest    | Posttest  | Pretest    | Posttest  |
| Appropriate                       | Experiment     | 0          | 19        | 0          | 20        | 0          | 18        |
|                                   | (0.0%)         | (61.3%)    | (0.0%)    | (64.5%)    | (0.0%)    | (0.0%)     | (58.1%)   |
|                                   | Control        | 0          | 13        | 0          | 13        | 0          | 12        |
|                                   | (0.0%)         | (40.6%)    | (0.0%)    | (40.6%)    | (0.0%)    | (0.0%)     | (37.5%)   |
| Inappropriate                     | Experiment     | 5          | 10        | 6          | 8         | 4          | 8         |
|                                   | (16.1%)        | (32.3%)    | (19.4%)   | (25.8%)    | (12.9%)   | (25.8%)    |
|                                   | Control        | 6          | 14        | 6          | 13        | 4          | 12        |
|                                   | (18.8%)        | (43.8%)    | (18.8%)   | (40.6%)    | (12.5%)   | (37.5%)    |
| No Explanation with justification | Experiment     | 16         | 2         | 15         | 3         | 16         | 5         |
|                                   | (51.6%)        | (6.5%)     | (48.4%)   | (9.7%)     | (51.6%)   | (16.1%)    |
|                                   | Control        | 14         | 5         | 15         | 6         | 14         | 8         |
|                                   | (43.7%)        | (15.6%)    | (46.9%)   | (18.8%)    | (43.8%)   | (25.0%)    |
| No explain                        | Experiment     | 10         | 0         | 10         | 0         | 11         | 0         |
|                                   | (32.3%)        | (0.0%)     | (32.3%)   | (0.0%)     | (35.5%)   | (0.0%)     |
|                                   | Control        | 12         | 0         | 11         | 0         | 14         | 0         |
|                                   | (37.5%)        | (0.0%)     | (34.8%)   | (0.0%)     | (43.8%)   | (0.0%)     |

Based on the data in the table above, it appears that there is a change in scientific explanation ability of students in both groups to the better direction of the state before following the learning to the state after following the learning. For the appropriate category there was an increase in the number of students in both groups from the pretest to the posttest, if at the time of pretest none was in the appropriate category, at the time of posttest there were 19 students in the experimental group and 13 students in the control class in this category. Conversely for the category No explain there is a decrease in the number of students in both groups from the time of pretest to the posttest, if at the time of pretest there are 10 students in the experimental class and 12 students in the control class which is in the category No explain, at posttest none of the students in the experimental class and in the control class in this category. This shows the application of QD-LOIBI in the study of kinetic gas theory material can facilitate scientific explanation ability. When compared between the experimental and control groups, it appears that the number of students in the experimental group in the appropriate explanation category is greater than the number of students in the control class. In contrast, the number of students in the experimental group in the No explanation with justification category is smaller than the number of students in the control class. This shows that the presence of visual multimedia in teaching materials developed for the application of QD-LOIBI can further improve the scientific explanation of high school students.

Table 3 shows the number of students in the experimental and control classes in each scientific explanation quality category.
From the data in the above table it appears that when the appropriate explanation category is classified again by quality, it turns out that most students in both groups are in categories 1 and 2. Only a small percentage of students in both groups are in category 3 which is the most scientific explanation quality category high. These data indicate that the learning treatment applied to the two classes has not been able to facilitate the students to achieve optimum scientific explanation quality. If re-comparison between the experimental and control groups is observed, the number of students in the experimental group in category 3 is greater than the number of students in the control group. Again this indicates the presence of visual multimedia in developed teaching materials for the application of QD-LOIBI can further improve the quality of scientific explanation of high school students.

The presence of various visual media such as video phenomenon and simulation / virtual animation on teaching materials greatly assist the construction process of understanding the learning content. According to Alrsa’i & Aldhamit, the use of computer simulations can help understand students about abstract physics material [12]. Similarly, Mirana states that the use of computer simulations in a constructivist approach can improve students' understanding of the content of physics [13]. In addition Esquembre also states that the use of computers in learning physics has a good potential in improving the understanding of physical content [14].

4. Conclusion
Implementation of Question-Driven Levels of Inquiry Based Instruction (QD-LOIBI) assisted visual multimedia supported teaching materials can further improve the scientific explanation ability of high school students compared to the application of Question-Driven Levels of Inquiry Based Instruction (QD-LOIBI) without visual multimedia supported teaching materials. These results indicate the power of the use of visual multimedia in support of students' understanding of the kinetic gas content.

5. References
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Table 5. The number of students’ explanations in each category in terms of the quality, for each item, for experiment and control group in the pre– and post-test.

| Categories in terms of the quality | Group      | Question-1 | Question-2 | Question-3 |
|-----------------------------------|------------|------------|------------|------------|
|                                   |            | Pretest    | Posttest   | Pretest    | Posttest   | Pretest    | Posttest   |
| Category 3                        | Experiment | 0 (0.0%)   | 5 (16.1%)  | 0 (0.0%)   | 5 (16.1%)  | 0 (0.0%)   | 4 (12.9%)  |
|                                   | Control    | 0 (0.0%)   | 2 (6.3%)   | 0 (0.0%)   | 3 (9.4%)   | 0 (0.0%)   | 1 (3.1%)   |
| Category 2                        | Experiment | 0 (0.0%)   | 8 (25.8%)  | 0 (0.0%)   | 9 (29.0%)  | 0 (0.0%)   | 9 (29.0%)  |
|                                   | Control    | 0 (0.0%)   | 6 (18.8%)  | 0 (0.0%)   | 5 (15.6%)  | 0 (0.0%)   | 8 (25.0%)  |
| Category 1                        | Experiment | 0 (0.0%)   | 6 (19.4%)  | 0 (0.0%)   | 6 (19.4%)  | 0 (0.0%)   | 5 (16.1%)  |
|                                   | Control    | 0 (0.0%)   | 5 (15.6%)  | 0 (0.0%)   | 5 (15.6%)  | 0 (0.0%)   | 3 (9.4%)   |
| TOTAL (Appropriate Explanations)  | Experiment | 0 (0.0%)   | 19 (61.3%) | 0 (0.0%)   | 20 (64.5%) | 0 (0.0%)   | 18 (58.1%) |
|                                   | Control    | 0 (0.0%)   | 13 (40.6%) | 0 (0.0%)   | 13 (40.6%) | 0 (0.0%)   | 12 (37.5%) |
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