Content analysis of misconceptions on bacteria in the biology textbook of high school

C Novitasari*, M Ramli and P Karyanto
Magister Pendidikan Sains, Universitas Sebelas Maret, Jl. Ir. Sutami 36A Surakarta, Jawa Tengah 57126, Indonesia

*chaerulnovita@gmail.com

Abstract. Misconceptions on bacteria found in several sub-concepts, i.e. characteristics, structure, classification, form and shape, reproduction, and classification of gram positive and negative bacteria. Textbook is one of the factors that can lead to misconceptions. Textbooks are the teaching aids and sometimes become the only source for student regarding the concepts. The aim of this research is to identify the misconceptions in high school biology textbooks and to categorize the misconceptions in high school biology textbooks particularly on the materials of bacteria. Two textbooks were selected purposively, as the books used in two targeted high schools. The misconception was categorized based on 5 categories according to Hershey, i.e. undergeneralizations, obsolete concepts and terms, oversimplifications, overgeneralizations, and misidentifications. The result shows that there are misconceptions on both textbooks that are 7.4% undergeneralizations, 2.5% oversimplifications, 0.6% overgeneralizations, and 0.6% misidentifications. Since the misconception dominated by categories of undergeneralizations and oversimplifications, it is predicted that it will stimulate difficulties of students to construct the complete concepts.

1. Introduction
Misconception means the discrepancy on the ways of interpreting a concept or, in other words, interpreting a concept differently from the concept given by the experts and commonly agreed [1]. Misconception is also called concept misinterpretation. Misconception is defined as the interpretation of concepts in an unacceptable statement [2]. The former misconceptions are very strong and firm, often difficult to be dispelled in formal learning [3]. The students’ poorly handled misconceptions can disrupt their thinking in accepting the subsequent knowledge resulting in less optimal learning [4,5].

According to a study conducted by Hashwesh (1986), the causes of students’ misconceptions were (1) the teacher was not aware of the students’ preconceptions, (2) the evaluation method used by the teacher failed to examine the concepts held by the students that turned out to be wrong answers, (3) generally, the teacher was not critical to the students’ answers that showed misconceptions, (4) the textbooks used by the teacher and the handbooks of students containing wrong concepts could lead to the students’ misconceptions [6]. The causes of misconceptions in general can be summarized into five factors: student, teacher, textbook, context, and teaching method [2].

A textbook can cause misconceptions if there are mistakes in explanations or descriptions in the materials contained in the textbook [7]. Textbook is an important teaching material for teachers because it can support the learning process and the students’ reading program. The misconceptions in textbook have fatal impact and lead to the students’ misconceptions [8].
Based on the previous studies carried out, it was revealed that there were some students who had difficulty in studying biology due to the complexity of concepts, terms or integration of the concepts on both microscopic and macroscopic scales, one of which was the concept of bacteria [9]. This is in line with the results of our initial study in which the misconception detection on bacteria on high school students of class X in Sragen—a regency in Central Java Indonesia by using Assessment for Learning (AfL) in the form of diagnostic test showed the occurrence of misconceptions on the sub-concepts of characteristics, structure, classification, forms, reproduction, and classification of gram-positive and gram-negative bacteria.

Based on the above-mentioned description, this study was conducted to analyze the contents of learning materials of bacteria in the biology textbooks for class X of high school in Sragen. The method of content analysis was divided into several sub-areas of content including book motivational factors (historical notes, author and researcher biographies), understanding guidelines (colors and graphs), assistance techniques, and philosophical positions [10].

This study aimed to identify the misconceptions in high school biology textbooks and to categorize the misconceptions in high school biology textbooks particularly on the materials of bacteria. The proposed research problems were: (1) how are the profiles of concepts of bacteria in the biology textbooks under examination? (2) What are the categories of misconceptions on the materials of bacteria in the textbooks? (3) what are the possible effects of misconceptions on the materials of bacteria upon the concepts that the students will construct?

2. Method

The research carried out was descriptive research using document content analysis method. Content analysis is a research method conducted to analyze the data in the forms of notes and documents [11]. The documents analyzed in this study were biology textbooks for class X of high school used in Sragen, particularly on the materials of bacteria. The biology textbooks used were two books developed based on Kurikulum 2013 and selected purposively (Table 1). To examine the wrong concepts in the textbooks, the concepts in reference books were checked. The reference books used in this study were Biology by John W. Kimball [12]; Biology, Eighth Edition Volume 2 by Campbell, et al [13]; and Biology: The Unity and Diversity of Life by Cesie star [14].

The textbooks were analyzed particularly on the concepts and sub-concepts of bacteria including the definition, characteristics, structure and its function, forms, reproduction, colors, ways of living, classification, beneficial and adverse roles, and prevention of dangers caused by bacteria, gram-positive and gram-negative bacteria, and endospore formation. The concepts in the textbooks were analyzed with reference to the literature that fitted the concepts of bacteria.

The categories of misconception were based on Hershey’s method consisting of five categories, namely undergeneralizations (generalization of concepts that are too narrow compared to literature concepts, obsolete concepts and terms (the concepts and terms that are no longer agreeable to up-to-date studies), oversimplifications (simplification of concepts in excess, so that the concepts stated by textbook/author(s) are incomplete and distorted from the author(s)’ points), overgeneralizations (generalization of concepts that are too broad so that the concepts are too general), and misidentifications (mistakes in identifying concepts that lead to wrong statements of concepts) [15].
Table 1. Characteristics of the textbooks under examination.

| Characteristics                          | Textbook A                      | Textbook B                      |
|------------------------------------------|---------------------------------|---------------------------------|
| Curriculum Reference                     | *Kurikulum 2013*                | *Kurikulum 2013*                |
| Year of Publication                      | 2013                            | 2016                            |
| Number of Pages                          | 470 pages                       | 194 pages                       |
| Number of Pages Containing the Materials of bacteria | 44 pages                       | 25 pages                       |
| Colors of Pictures                       | Black and white                 | Black and white                 |
| Number of Pictures                       | 32                              | 9                               |
| Size of Pictures                         | 1/6 – 1/3 page                  | 1/6-1/3 page                    |
| The Sequence of Materials                | - Definitions of archaeabacteria, eubacteria, and bacteria | - Characteristics               |
|                                         | - Characteristics               | - Structure                     |
|                                         | - Cell structure                | - Forms                         |
|                                         | - Gram-positive and gram-       | - Reproduction                   |
|                                         | negative bacteria               | - Colony morphology             |
|                                         | - Ways of living                | - Staining/ painting            |
|                                         | - Defence in threatening        | - Eubacteria Classification     |
|                                         | environments                   | - Roles                         |
|                                         | - Reproduction                  | - Ways of coping with           |
|                                         | - Classification                | harmful bacteria                |
|                                         | - Roles                         |                                 |
|                                         | - Breeding                      |                                 |
|                                         | - Efforts to avoid the dangers of bacteria |                   |
|                                         | - Cyanobacteria (blue-green      |                                 |
|                                         | bacteria)                       |                                 |

The research procedure comprised 1) observing the textbooks used in the state and private high schools in Sragen, 2) selecting the sample of textbooks using purposive technique, 3) analyzing the sub-concepts of materials on bacteria in the textbooks for the reference of analysis indicators, 4) writing the content analysis results of each sub-concept contained in the textbooks on the research instrument, 5) writing the content analysis results of each sub-concept contained in the reference books (literature) on the research instrument, 6) analyzing the textbooks and the reference books (literature) by comparing the contents of both of them following the misconception category guidelines in textbook by Hershey, 7) incorporating the analysis results into the table of analysis results on the research instrument, 8) performing content validation of the analysis results by the experts in bacteria.

3. Results and discussion

Based on the analysis results of misconception in the textbooks with the materials of bacteria using content analysis methodology, there were misconceptions in some categories. The highest category (in percentage) of misconception in the textbooks, based on Hershey’s categories, was undergeneralizations category. In addition, there was no ‘obsolete concepts and terms’ category found in the textbooks (Table 2).
Table 2. Percentage of misconception categories on sub-concepts of bacteria.

| Sub-concept                          | Textbook A             | Textbook B             |
|--------------------------------------|------------------------|------------------------|
|                                      | Misconception Category | Total of Misconception (%) | Misconception Category | Total of Misconception (%) |
| Definition of bacteria               | UG                     | 2.5                    | -                      | 0                        |
| Characteristics                      | UG                     | 1.2                    | UG                     | 2.4                      |
| Body structure                       | UG                     | 1.2                    | UG                     | 1.2                      |
| Forms                                | MI                     | 1.2                    | OG                     | 1.2                      |
| Reproduction                         | -                      | 0                      | -                      | 0                        |
| Ways of living                       | -                      | 0                      | UG                     | 3                        |
| Classification of bacteria           | -                      | 0                      | -                      | 0                        |
| Staining                             | -                      | 0                      | UG                     | 1                        |
| Classification of gram-positive and gram-negative bacteria | OS                   | 2.5                    | -                      | 0                        |
| Roles of bacteria                    | UG                     | 1.2                    | -                      | 0                        |
| Prevention of dangers of bacteria    | -                      | 0                      | -                      | 0                        |

In Table 2, it is seen that there were some misconceptions found on the sub-concepts of definitions of bacteria, characteristics, body structure, reproduction, staining, classification of gram-positive and negative bacteria, and roles of bacteria. 81 concepts were analyzed on both textbooks. The results showed the percentages of each misconception category in Textbook A which were undergeneralizations/UG (6.2%), oversimplifications/OS (2.5%), misidentifications/MI (1.2%), and obsolete concepts and terms/OCT as well as overgeneralizations/OG (0%). Furthermore, the percentages of misconceptions in Textbook B were under generalizations/UG (8.6%), oversimplifications/OS (2.5%), overgeneralizations/OG (1.2%), and obsolete concepts and terms/OCT and misidentifications/MI (0%). The biggest misconception on both textbooks was in the category of undergeneralizations with an average of 7.41%. Under generalization is a category of misconceptions characterized by the existence of a concept that is stated to refer only to some biological object or problem, and the expressed statements can only be used to formulate some concepts or problems. Additionally, the existence of undergeneralizations in textbooks affects the students’ lack of understanding of a certain concept so that students do not comprehend the whole concept in detail, and it eventually leads to misconception if it is not provided with the teacher’s explanation [16]. The percentages of overall bacteria concept analysis results in both textbooks are presented in Figure 1.
The misconceptions about the concepts of bacteria in textbooks have impacts on students’ conceptions [8]. Additionally, misconceptions in literatures, one of which is in textbooks, can highly cause students’ and teachers’ misconception [17]. Textbook, which refers to the book used in the learning process, becomes the students’ guide in discovering the concept that has not been understood from the teacher's explanation. Therefore, if there is misconception in the textbook, it strongly impacts the students’ conceptions [18]. Several results of content misconception analysis of sub-concepts of bacteria found in both textbooks are presented in Table 3.

### Table 3. Results of misconception analysis of textbooks’ contents.

| Misconception categories | Misconceptions in the textbooks                                                                 | Predicted misconception impacts                                                                 |
|--------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| **Undergeneralizations** | • Bacteria live in solitary and colony (no detail explanations and no images)                 | • Students are unable to differentiate between colony and solitary.                                |
|                          | • Bacteria have cell walls and generally have non-chlorophyll cell walls (no images).          | • Students are able to conclude that other organisms have chlorophyll cell walls.                 |
|                          | • Sexual reproduction is in form of transformation, transduction, and conjugation which are briefly described using images without giving further explanation about the images. | • Students cannot understand the stages of sexual reproduction of bacteria completely and clearly without clear description of the stages. |
|                          | • Bacterial decomposers (saprobe) denitrify dead plants / animals, as well as organisms’ residual / feces. | • Students are able to conclude that bacteria can denitrify organic compounds. However, according to experts, bacteria are also able to denitrify the inorganic compounds. |
| **Oversimplifications**  | • Bacteria are unicellular which consist of one cell (no images).                               | • Students are unable to elaborate the concepts of unicellular in detail.                         |
|                          | • Bacteria are prokaryotic (have no nucleus membrane).                                         | • Students may have misconception about the definition of prokaryotic.                           |
|                          | • Classification of gram-positive and negative bacteria is based on differences in polypeptide thickness. | • Students are unable to understand completely that the experts classify the cells based on its cell walls composition. |
| **Overgeneralizations**  | • Additional bacterial structures are in the form of endospores.                               | • Students may have misconception about endospores.                                              |
| **Misidentifications**   | • Flagella are whip feathers composed of protein compounds, located on the cell wall.         | • Students may have misconception related to the location of flagella bacteria.                   |

**Figure 1.** Percentage of misconception on both textbooks.
Misconception categories in textbooks have different predicted impacts on students’ understanding. Firstly, the misconception category of undergeneralizations makes the students understand only certain parts of the concepts; hence, the students cannot comprehend the overall concept in detail [16, 19]. Based on the results of misconceptions analysis on the concept “the bacteria live in solitary and colony (without detail explanation and image)”, it was revealed that the students were unable to distinguish between solitary and colonies. According to literature, it is called colony when bacteria coincide without interruption. Furthermore, several types of bacteria converge temporarily or permanently within the colony [14].

Misconception category of oversimplifications in textbooks gives impacts on students in which they cannot fully comprehend the concepts, but partly comprehend some listed concepts in the books, thus it potentially causes misconceptions among students [16]. The example of misconception in textbooks was the statement of “bacteria is a unicellular consisting of one cell (without image)”. This statement made students unable to define a characteristic of unicellular which is, according to literature, as an organism that has the organized organelles and performs life functions within a single cell [14]. The second example was the statement of “bacteria is prokaryotic (does not have a cell nuclear membrane)”. Based on the experts’ concepts, prokaryotic organisms are organisms that do not have nuclear membrane and membrane-shielded organelles, have only one chromosome, and do not have histones that join the chromosome [14].

Furthermore, overgeneralizations tend to make students unable to understand the real concept due to the fact that the concept in textbooks is too general [16]. Based on the results of the misconception analysis, the statement “the additional structure of bacteria is in the form of endospores” caused students’ misconception. According to the literature, endospores are resistant cells which are formed by bacteria when lacking of essential nutrient. The initial cell produces copy of its chromosomes and encloses a solid wall forming the endospores. Water is removed from the endospores and its metabolism stops. The rest of the initial cell is destroyed and then leaves only the endospores. If the environment is more suitable, the endospores may remain dormant but may live for centuries, rehydrating and resuming metabolic processes as their environment improves [14]. Lastly, misidentifications category can make students experience a fatal misconception as the concepts expressed in textbooks are inconsistent with the literature or expert [16, 18]. Based on the results of misconception analysis, there was a wrong statement found in the textbook, “flagella are whip feathers composed of protein compounds, located on the cell wall.” Based on the literature, flagella are tethered to the cell membrane and extend out through the cell wall. It is commonly used by bacteria for swimming or as moving tools [13].

4. Conclusions
The results of this study revealed that misconception category of under generalizations was found in the concepts of archaeabacterial and eubacteria, characteristics, structure and functions of bacteria, sexual reproduction, gram staining / bacteria painting, the role of bacterial decomposers in both textbooks. Furthermore, oversimplifications category was found in the concepts of grouping of gram-negative and gram-positive bacteria, bacteria features related to prokaryotic organisms and unicellular cell. Then, the misconception of the additional structure of endospores concept was in overgeneralizations category. Lastly, the category of misidentifications was found in the concept of flagella bacteria. In others concepts, there was no misconception.

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