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Research Article

The difficulty index of biology topics in Indonesian Senior High School: Biology undergraduate students' perspectives

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ABSTRACT

Biology is a subject that contains of many difficult concepts to study. This study aimed to identify Biology topics taught in Senior High School (SHS) which were considered as difficult materials by undergraduate students. The data were gathered by means of a web-based survey from 198 Biology students of 25 universities and 51 Biology education students of nine universities in Indonesia. The biology students graduated from SHSs in 97 regions/municipality, while the biology education students were graduated from 34 regions/municipality. The data were analyzed using two formulas: 1) Biology Difficulty Index (BDI) to determine the difficulty index of Biology subject, and 2) Topic Difficulty Index (TDI) to examine the difficulty index of each Biology topics. The results showed that the highest value of TDI was Genetics. There was no significant difference of BDI between Biology students and Biology education students. The lower of the students' BDI, the higher the level of their interest in Biology subject. The primary cause of difficulty encountered by the students in studying various topics of Biology was the complicated characteristics of the materials. The findings of this study can be followed up by designing diagnostic tests and instructional designs in biology topics which consider students' difficulty.

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INTRODUCTION

Indonesian students have often been reported as having poor academic competence. Several previous researches showed that they slightly have twenty-first-century skills (Amin et al., 2017; Jua et al., 2018). The twenty-first-century skill, especially HOTS, will be hardly acquired by students if they are difficult to understand the topics being taught during the learning process. Understanding is a basic level of cognition (Adams, 2015). Thus, if the students are not well equipped with the basic level of cognition, they will have difficulty to reach higher cognitive levels (Kamarulzaman et al., 2017). Moreover, the level of students' understanding is reported to have a significant correlation with their thinking skills (Andayani et al., 2018). Therefore, identifying difficult topics and the factors causing the difficulty is crucial as an effort to improve the quality of twenty-first-century learning.

In some countries, the identification of subjects and difficult topics have been conducted. A study conducted by Şahin, Meltem, Oya, and Erdal (2014) informed that several subjects are more difficult for students than others. While most of the studies focused on identifying the difficult topics of a particular subject (Buah & Akuffo, 2017; Çimer, 2012; Etobro & Fabinu, 2017; Tekkaya et al., 2001), some researchers limited their studies to identify sub-topics of the difficult topics (Awang-kanak et al., 2016; Morris, 2018). These subjects and difficult topics, further, lead to other effects, such as students' subject choices and motivation to involve in the learning process (Shirazi, 2017). Therefore, it is not surprising that most of the students tend to not to be interested in science subjects, such as Biology.

Understanding the topics of Biology subject is not an easy task. A misconception often occurs when the students try to deal with those topics (Lukša, Radanović, Garašić, & Perić, 2016; Svandova, 2014). It is supported by the fact that the students have a poor academic achievement (Hasibuan & Djulia, 2017) and are slightly well-performed in International science competition (Sari, 2012). The difficulty of learning Biology is not only experienced by Indonesian students, but also by students of other countries. The result of a study conducted by Çimer (2012) showed that Turkish students were difficult to learn material cycle, endocrine system, aerobic respiration, cell division, gene and chromosome. The other result of the study that was also conducted in Turkey revealed that physiology, genetics and cytology were categorized as difficult Biology topics (Gungor & Ozkan, 2017). In a similar direction, the study carried out by Etobro & Fabinu (2017) also informed that Nigerian students experienced difficulty in learning some topics of Biology subject.

Researches on classifying the difficult Biology topics is highly necessary as an attempt to facilitate students in learning Biology. Alfiraida (2018) conducted research on difficult Biology topics in an Indonesian education context. The result showed that Coordination System and Immune System were respectively the most difficult for the students. Similarly, Fauzi & Mitalistiani (2018) reported that Genetics, Metabolism, and Immune System were the most three difficult Biology topics for the students. However, the previous studies did not involve wide scopes of the research context and had a minimal number of educational institutions. Fauzi & Mitalistiani's (2018) study, for instance, only selected the participants from a University in Malang, while Alfiraida's (2018) study involved several students and teachers of 9 Senior High Schools in Salatiga municipality.

Considering that the identification of difficult topics in Biology subject is crucial, research involving a greater number of respondents with a heterogeneous setting should be conducted. Research classifying difficult Biology topics by employing a great number of respondents from various regions in Indonesia is still scant until today. Therefore, the purpose of this study was to fill the gap by identifying Biology topics of Senior High School that are considered as difficult by undergraduate students of Biology from various regions in Indonesia. Besides involving a greater number of respondents, the present study has some characteristics which make it different from other previous studies. First, this study analyzes the difference of difficulty index of every Biology topic in Senior High School. Second, this study also examines the difference of difficulty index of every Biology topic between students of Biology and students of Biology education. Third, this study evaluates the relationship between the difficulty index of every topic and the level of students' interests toward Biology subject in Senior High School.

The findings of this study are highly expected to give valuable benefits and insights for future researches. The result of topics classification can be used by future researchers as a reference to conduct a study focusing on the improvement of students' understanding of the concepts of these topics. The existence of the difficult topics should be discussed in detail analysis, thus, the difficult concepts associating with these topics are well-categorized. Furthermore, by examining the relationship between the difficulty index and the students' interests in Biology subject, future researches analyzing the importance of minimizing the number of difficult topics to improve students' awareness to learn Biology is conducted. Last but not least, the result of this study can be used to confirm the association between the difficulty index experienced by students and their decision in choosing a study program at university.

METHOD

This survey study was designed to examine difficult Biology topics as seen from the perspective of Senior High School graduates. Also, this study aims to analyze the influence of the difficult topics and study program on the difficulty index as well as to evaluate the correlation between the difficulty index of every topic and the students' interests in Biology subject. Hence, the procedures of data collection and data analysis employ a quantitative approach.

The data collection process was carried out during 2019. The participants of this study were limited to Indonesian Senior High School graduates who were studying in undergraduate program majoring in Biology and Biology education. The participants of this study were those who were willing to fill out the questionnaire

which was used as an instrument for collecting the research data. Questionnaires are in the online forms and are distributed through social media and e-mail. Furthermore, the undergraduate students who completely filled out the biodata in the questionnaire were positioned as participants as long as they met several criteria. These criteria are biology/biology education students who were Indonesian citizens, become students in one of the tertiary institutions in Indonesia, and graduate from senior high school in Indonesia.

The online questionnaire was designed using Google forms and consists of two parts. The first part dealt with the participants' personal identity and the second part was addressed to examine the students' perspectives about Biology topics of Senior High School. The personal identity included name, gender, age, semester, study program, university, name of Senior High School, and level of the students' interests in Biology (ranging from dislike until favorite). In the second part, the participants were asked to determine the difficulty level of the topics. Listed in the questionnaire, there were 19 topics of Biology based on the Senior High School curriculum that was being implemented in Indonesia. The participants were required to respond to every topic by choosing one of four available options: a) easy (I understand the topics without any difficulty); b) neutral (I have difficulty but I still understand the topics); c) difficult (I cannot understand the topics); and d) I never study the topics. Furthermore, the participants were asked to choose the reason(s) representing their opinion on why the topics are difficult.

The questionnaire was then distributed through some online platforms available in Indonesia, such as Whatsapp, email, etc. After several months, 198 Biology students and 51 Biology education students filled out the questionnaire. The Biology students were from 25 universities in Indonesia, and the Biology education students came from 9 universities. Based on the respondents' identity, the Biology students were graduated from Senior High Schools in 97 regions/municipality in Indonesia, while the Biology education students were from 34 different regions/municipality. The distribution of regions/municipality Biology students' Senior High Schools was presented in Figure 1, while Figure 2 depicted the distribution of regions/municipality where Biology education students came from.

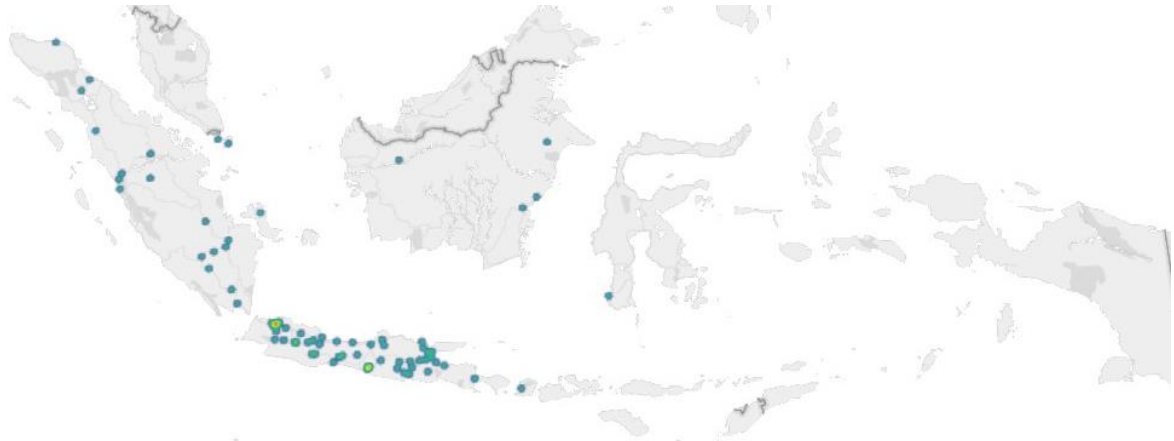

Figure 1. Senior High School location of Biology Students as the participants in this study

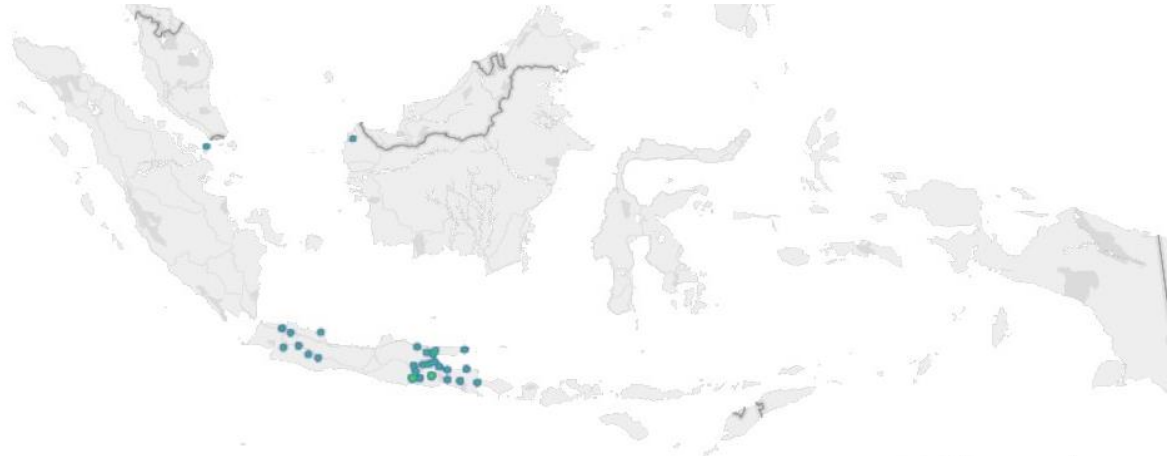

Figure 2. Senior High School location of Biology education students as the participants in this study

After the data were collected, the level of students' interests in Biology subject of Senior High School was converted into ordinal data: 0 = dislike, 1 = neutral, 2 = like, 3 = favorite. The students' responses toward every topic were also converted into ordinal data: 0 = never, 1 = easy, 2 = neutral, and 3 = difficult. The students' difficulty level of Biology subject was calculated by using Biology Difficulty Index (BDI) as showed in Formula 1,

while the difficulty of every topic was counted by using Topic Difficulty Index (TDI) (Formula 2) (Buah & Akuffo, 2017).

$$BDI = \frac{\text{The number of difficult topics x 100}}{\text{The stated topics – The number of topics that have not been studied}} \quad (1)$$

$$TDI = \frac{\text{The number of students who argue difficult x 100}}{\text{The number of participants – The number of students who state that they have not studied the topics}} \quad (2)$$

Moreover, statistics analysis was administered to reveal some other findings. Kruskal-Wallis test followed by the post hoc test (multiple comparisons using Mann-Whitney with Bonferroni correction) was utilized toward the difficulty ordinal response of every student in each topic. The purpose of this analysis is to categorize which difficult Biology topics that are significantly different from the other topics. In addition, the Mann-Whitney U test was employed to identify the existence of TDI which significantly differs in each analyzed topic. This analysis aimed to examine the significant difference of the BDI between the Biology students and the Biology education students. Spearman's rho correlation test was also conducted toward the BDI data with the ordinal data of students' interest level in Biology subject to find out their correlation. Furthermore, Pearson's chi-square test was administered toward the ordinal data of students' interest level and the ordinal data of students' difficulty level of each topic. Through this analysis, the association between the interest level and the difficulty level of each topic was evaluated. Last but not least, the percentage was used to classify the causes of difficulty learning experienced by the students in various topics of Biology.

RESULTS AND DISCUSSION

Biology is one of the science subjects taught in Indonesian Senior High School. In order to identify which topics considered as difficult by the students, the ranking of students' difficulty responses was calculated. The Kruskal-Wallis analysis on the data ranking informed that there was a significant influence of the Biology topics on the difficulty responses faced by the students. Furthermore, the post hoc was conducted and the result was presented in Table 1.

Table 1 Summary of pos hoc test on the students' different responses toward Biology topics of Senior High School

Topics	Difficulty response	notation								
Laboratory safety	1.0843	a								
Environmental pollution	1.2771	a	b							
Scope and object of biology	1.2851		b	c						
Biodiversity	1.3775		b	c	d					
Ecosystem	1.4355		b	c	d					
Growth and Development	1.5060			c	d	e				
Reproduction system	1.5663				d	e	f			
Animalia	1.6613					e	f	g		
Plantae	1.6667					e	f	g		
Cell Division	1.6747					e	f	g		
Fungi	1.6988						f	g	h	
Evolution	1.7510						f	g	h	
Protista	1.7912							g	h	i
Bacteria	1.8233							g	h	i
Virus	1.8835							g	h	i
Immune system	1.9157								h	i j
Metabolism	1.9679									i j
Coordination system	2.0080									i j
Genetics	2.1807									j

Based on Table 1, Genetics is the most difficult topic as seen from the students' perspective. Moreover, Table 2 indicated that the TDI of Genetics was relatively higher than the other topics, both in Biology students and Biology education students. This finding emphasized Genetics as the most difficult topic in Biology as reported by previous finding (Fauzi & Mitalistiani, 2018). In addition, it was also considered as the most difficult course at the university level (Fauzi & Fariantika, 2018). Other studies conducted in various countries also informed that Genetics was one of the most difficult topics in Senior High School (Çimer, 2012; Tekkaya et al., 2001; Topçu & Şahin-Pekmez, 2009). The result of Agboghoroma & Oyovwi's (2015) in Nigeria reported that Genetics was not only perceived as a difficult topic but also considered as very difficult by the students.

One of the reason is most of the students were able to memorize the concepts of Genetics, but they did not understand the materials being studied (Topçu & Şahin-Pekmez, 2009).

Table 2 Summary of Mann-Whitney U test of TDI between Biology students and Biology education students

Topics	TDI		Mann-Whitney U	Asymp. Sig. (2-tailed)
	Biology student	Biology Education student		
Growth and development	4.040	0.000	4209.000	0.037
Metabolism	11.675	14.000	4928.000	0.733
Genetics	37.949	43.137	4437.000	0.151
Cell division	6.633	8.000	4288.000	0.061
Evolution	11.735	8.000	4975.000	0.857
Coordination system	20.812	25.490	4711.500	0.407
Reproduction system	3.030	1.961	5011.000	0.925
Immune system	19.895	25.000	4960.500	0.831
Laboratory safety	1.081	0.000	4943.500	0.749
Scope and objects of biology	0.543	0.000	4935.500	0.775
Virus	17.436	20.000	5044.500	0.991
Bacteria	8.673	12.245	5010.000	0.919
Protista	9.744	11.765	5024.500	0.951
Fungi	5.128	1.961	4735.500	0.422
Biodiversity	3.093	0.000	4903.000	0.709
Plantae	7.732	11.765	4267.500	0.058
Animalia	6.599	3.922	4961.000	0.876
Ecosystem	3.046	0.000	4817.000	0.600
Environmental pollution	1.036	0.000	4819.000	0.537

Coordination and Immune System was the second highest topics thad perceived difficult by undergraduate students. When the students studied Organ System, both Coordination and Immune System, the discussion was not only about one component in the human body, but also about other the other related components. In addition, the students must also learn all process occurred in the Organ System. These complicated materials become the primary reason why this material was difficult to be studied by the students (Lieu et al., 2018). This finding is consistent with what has found by Alfiraida (2018) in her study which concluded that the difficulty of Coordination and Immune System was caused by the complicated characteristics of the topic. Besides, most students encountered difficulty in using the definition of an organ to identify and differentiate one organ and other organs in the human body (Cherif et al., 2010). The huge number of materials in Biology subject made the students to only do memorization, instead of understanding the concepts of the topic (S. A. Miller et al., 2002).

The topic of Coordination System generally consists of three parts, namely Neuron, Endocrine, and Sensory System. In relation to the finding of this study, research conducted by (Lieu et al., 2018) reported that more than 61% of students had difficulty in learning Neuron System. The other finding of a study conducted in Turkey revealed that Endocrine System was one of the five difficult topics encountered by the students (Çimer, 2012). Then, beside those topics, metabolism was also the most difficult topic. This finding confirms the result of the study conducted by Muspikawijaya, Iswari, & Marianti (2017) that the students are still lack of the acquisition of Metabolism process because this topic consists of chemical reactions and scientific terms. Thus, the topic of Metabolism is often seen as a challenging topic of Biochemistry, both for students and teachers (Cicuto et al., 2019). As a result, Metabolism has developed and attracted the attention of many researchers, academicians, and practitioners in teaching this topic to the students (Tibell & Rundgren, 2010).

After examining the difficulty index of each topic, the difficulty index of Biology as a subject was determined through BDI. The result reported that the BDI of Biology students was 9.715, while the BDI of Biology education students was 9.833. However, from Table 3 we can see that the BDI of the two groups was not significantly different ($U = 5014$, $p = 0.938$). This finding indicates that the level of difficulty of students when studying biology in high school is less able to be a factor influencing their decision to choose a biology or education major when they enter college. This finding is in line with the previous finding conducted by Cuff (2017) which informed that students' perceptions toward the difficult subject closely related to their choices of the study program, but were not the main consideration in making a decision. On the other hand, the promising career and economic background are two factors that greatly influence the students' choices (Abubakar, 2017). Also, the social background is a factor determining the students' decision of their academic field (Keshishian et al., 2010).

However, in contrast to the decision to choose a college major, the results of the study indicate that the level of difficulty of students in studying biology is correlated with the level of students' interests on this subject. The result of Spearman's rho analysis was presented in Table 4. As shown in the table, the difficulty level of the students in learning Biology negatively correlated with their level of interest in this subject (ρ = -

0.181, p = 0.004). This result informs that the more the students experience difficulty in learning Biology topics, the more they are not interested in this subject. As a result, it can be implied that students' difficulty perceptions toward Biology is the main factor that inhibits students' interest in this subject. Level of students' interest is a primary factor influencing the success of learning. If a student experiences difficulty in learning a certain subject, their motivation and efficacy will decrease. This statement is based on a report from England that students' interest and motivation in learning science depend upon teachers' practice and students' perception toward the subject (Shirazi, 2017). Another finding from Myanmar also informed that the level of difficulty significantly correlated with students' interest and motivation in learning Biology (Soe, 2018). Moreover, a study conducted in Brazil and Portugal revealed that the students' interest and motivation significantly decreased since they experienced difficulty in understanding the concept of Biology (da Silva et al., 2016). In fact, motivation is the main factor for students' successful learning (Albrecht & Karabenick, 2018; Kappe & Flier, 2012). Therefore, perhaps, one of the causes of the low biology learning outcomes of high school students in Indonesia is due to their low interest in this subject.

Table 3 Summary of Mann-Whitney test of BDI between the students of Biology and Biology education

BDI		Mann-Whitney U	Asymp. Sig. (2-tailed)
Biology	Biology Education		
9.715	9.833	5014,000	0.938

Table 4 Summary of Spearman's rho correlation test between the BDI with the level of students' interests in Biology

Sources	Value
Correlation Coefficient	-0.181
Sig. (2-tailed)	0.004
N	249

Last but not least, the cause of students' difficulty in understanding each topic of Biology was identified. The summary of these factors is presented in Table 5. Based on the table, the complexity of the materials was the main cause of students' difficulty in learning Biology. Every Biology topic consists of a lot of information in it and it makes the topic complicated for the students, even complexity is the nature of Biology. It is due to the complex system is exists in all parts of life, from a molecule until the biosphere (Mazzocchi, 2008). However, learning a complicated concept makes teachers and students lack interest and motivation (Carty, 2012). Therefore, biology teachers should be creative in designing learning activities to make students easy in understanding the concepts and materials of Biology. Interestingly, the students' learning habit is the second cause of their difficulty in learning Biology topics. Their lazy habit of learning is closely related to their lack of metacognitive awareness. Indonesian students have often been reported as having poor metacognition (Nurajizah et al., 2018). In fact, it is undeniable that students having good metacognition will be aware of the importance of learning, the process of their learning, and the evaluation of their learning (T. M. Miller, 2017; Patterson, 2011).

In addition to the two factors, the abstract of the Biology concepts also becomes a factor contributing to the students' difficulty in learning Biology (Tabel 5). The concept is said to be abstract if the students do not have clear references presented in their thought (Bolognesi & Vernillo, 2019). In relation to this, the abstract concept and the fact that various Biology activities are hard to define is also reported as a natural characteristic of Biology material and becomes the primary factor of difficulty in learning Biology (Çimer, 2012).

Although the result of this study indicates that Biology consists of difficult concepts, it is undeniable that this science subject should be acquired by students. Biology is a branch of science which development is rapidly growing and is very beneficial for other human fields. The advanced development of Biology can be seen from its scope that not only focuses on cell but also concerns on molecules (Leemans, Braakhuis, & Brakenhoff, 2011; Paugh et al., 2010; Hardin, 2011; Rooney, Shukla, Wu, Getz, & Hacohen, 2015). The rapid development of technology results in some valuable invention including in Biology, such as biosensor (Sigolaeva et al., 2014), biology computation (Mirams et al., 2013), bioinformatics (Verk et al., 2011), biomarker (Martyniuk et al., 2012), and nanotechnology (Wong et al., 2013). The complexity of Biology and its benefits for other fields indicate that education today is challenging, in which its process should contribute to developing qualified human resources. The integration of Biology in other fields proves that Biology is very important to be studied. For instance, the contribution in the medical field is highly needed to identify a disease, to classify patients, and to explain the therapeutic effect based on its classification (Gonzalez-Angulo et al., 2010). Moreover, Biology is beneficial to improve the quality of life through its involvement in farming (Guillemaud et al., 2012), animal husbandry (Bateson & Feenders, 2010), and food industry (Rymbai et al., 2011).

Table 5 Summary of difficulty causes Percentage of each Biology topic in Senior High School

Topics	Factors (%)						
	Abstract	Complex	Mis-conception	Availability of learning sources	Teacher factors	Not supported by practicum	Bad self-study habits
Genetics	17.4	35.6	9.8	5.8	9.5	7.4	14.5
Coordination system	13.8	35.3	6.9	6.9	8.7	9.3	19.2
Immune system	19.8	34.3	5.9	6.9	10.6	3.7	18.8
Virus	18.2	31.1	8.3	10.6	8.3	4.6	18.9
Metabolism	15.4	35	7.3	4.2	12	9	17.1
Evolution	21.7	16.2	15.1	9.9	12.5	3.6	21
Bacteria	17.8	30.2	8	8	8.7	8.4	18.9
Protista	17.3	28.5	8.7	9	7.2	7.9	21.4
Plantae	9	31.9	7.8	7.3	11.8	9.8	22.4
Cell division	16.9	23.1	10.4	8.1	11.5	10.8	19.2
Animalia	6.3	39.6	4.6	0	10	12.1	27.4
Fungi	15.1	22.4	9.7	8.9	8.1	12.7	23.1
Reproduction system	11	29.7	11	4.2	10.6	9.3	24.2
Growth and development	11.4	15.5	11.8	7.1	15.6	16.6	0.2
Biodiversity	7.4	19.7	11.8	10.8	8.9	10.3	31.1
Ecosystem	9.4	20.6	9.4	9.4	9.8	12.1	29.3
Environmental pollution	8	15.5	9.6	11.8	9.1	16	30
Scope and objects of biology	14.4	10.6	12.2	12.8	11.7	6.1	32.2
Laboratory safety	8.5	4.9	12	10	11.3	25.6	27.7
Mean	**13.62**	**25.25**	**9.49**	**7.98**	**10.31**	**10.28**	**21.93**

To equip the students with the understanding of some difficult Biology topics, teachers must be able to design innovative and effective learning. If Indonesian Biology teachers still perform conventional and teacher-centered learning, the students will not be well-equipped with the acquisition of Biology materials. In terms of this, the Biology teachers can use several learning models that have been suggested by the previous researchers, such as the implementation of organism model in learning, cooperative learning, problem-based learning, and other models of learning. In this case, teachers are highly required to create an interesting learning activity that encourages students' involvement in learning Biology. In addition, they must also be able to improve students' metacognitive so that their learning habit changes. Furthermore, in terms of the abstract concept of Biology, teachers should be able to contextualize the learning materials so that the students will be easy to understand these materials.

CONCLUSION

The present study has identified the difficult Biology topics of Senior High School. The result concluded that the difficulty index in learning Biology was not significantly different between the students of Biology and the students of Biology education. Among 19 stated Biology topics, there was only the Growth and Development topic in which the difficulty index differed significantly between the two groups of the students. The other finding showed that Genetics was considered as the most difficult topic by the students, although it was not significantly different from Regulation System, Immune System, and Metabolism. This study also reported that the difficulty index of Biology subject negatively correlated with the level of students' interests in this subject. Last but not least, the finding of this study informed that the primary challenge of the students in learning Biology topics was the complicated characteristics of the materials.

Based on the aforementioned findings, some recommendations are addressed to further researches. First, a study on Genetics as the most difficult topic among the stated 19 topics should be conducted. The study can identify the difficulty level of subtopics in Genetics. It is highly needed to investigate the difficulty encountered by students in a more detailed understanding. Second, in terms of the complicated materials of Biology, therefore, further researches are highly suggested to integrate learning innovation that will assist students in understanding the Biology materials.

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