Journal for the Education of Gifted Young Scientists, 8(3), 1071-1085, Sept 2020
e-ISSN: 2149- 360X
jegys.org

youngwisepub.com

Research Article

Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test

Andi Andariana[1], Siti Zubaidah[2]*, Susriyati Mahanal[3], Endang Suarsini[4]

Universitas Negeri Malang, Faculty of Mathematics and Natural Sciences, Indonesia

Article Info

Received: 04 April 2020
Revised: 12 July 2020
Accepted: 29 August 2020
Available online: 15 Sept 2020

Keywords:
Students' misconception
Biology
Diagnostic test

2149-360X/ © 2020 The Authors. Published by Young Wise Pub. Ltd. This is an open access article under the CC BY-NC-ND license

Abstract

University students' misconceptions have become an important issue to discuss as prior concepts brought by the students into the classroom can affect the acquisition of new information. The current study attempted to identify Biology students' misconceptions in Human Anatomy and Physiology courses through a three-tier diagnostic test. The participants of this study were 128 students from the Department of Biology Education who were currently enrolled in Human Anatomy and Physiology courses at the Institute of Teacher Training and Educational Sciences (STKIP) Pembangunan Indonesia in Makassar. A three-tier diagnostic test was used as the instrument to identify the number of participants who had developed misconceptions about the concepts introduced in the courses. The test contained 23 items of Certainty of Response Index (CRI) that, on average, achieved a validity score of 0.426 and a reliability score of 0.794. The research data were analyzed using descriptive statistics. The results of the test analysis showed that the majority (61.51%) of the students developed misconceptions in Human Anatomy and Physiology courses. In detail, there were several misconceptions in 57.81% skeletal system, 52.34% muscular system, 55.47% integumentary system, 51.04% nervous system, 54.69% endocrine system, 66.02% hemolymphatic system, 62.89% cardiovascular system, 68.75% respiratory system, 70.31% digestive system, 70.70% urinary system, and 71.88% reproductive system. Misconceptions were mostly developed on reproductive system sub-materials and less likely found in nervous system sub-materials. Given this information, it can be concluded that the misconceptions of Biology students from the Institute of Teacher Training and Educational Sciences (STKIP) Pembangunan Indonesia in Human Anatomy and Physiology courses are categorized as high. Therefore, there should be an effort to deal with this issue.

To cite this article:

Andariana, A., Zubaidah, S., Mahanal, S., Suarsini, E. (2020). Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test. *Journal for the Education of Gifted Young Scientists*, *8*(3), 1071-1085. DOI: http://dx.doi.org/10.17478/jegys.752438

Introduction

For the last four decades, researchers worldwide have conducted investigations to identify student misconceptions at different levels of education (Arslan, Cigdemoglu, & Moseley, 2012). Research on student misconceptions has also been performed in various disciplines, such as in Mathematics and Science (Kaltakci-Gurel, Eryilmaz, & McDermott, 2016; Hebe, 2020; Putranta & Supahar, 2019; Ramadianti, Priatna, & Kusnandi, 2019). Thus, some misconception-related terms have been formulated, including alternative conceptions, alternative frameworks, naive beliefs, preconceptions, naive ideas, and pre-scientific ideas (Caleon & Subramaniam, 2010; Engelhardt & Beichner, 2004; Odom & Barrow, 1995). Misconceptions occur due to the incompatibility of student conceptions with the common

[1] Doctoral Program Student in Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Biology Education Department, STKIP Pembangunan Indonesia Makassar, Indonesia. **Email**: andi.andariana@stkippi.ac.id, ORCID No: 0000-0003-3876-6530
[2] Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. **Email**: siti.zubaidah.fmipa@um.ac.id, ORCID No: 0000-0002-0718-6392
[3] Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. **Email**: susriyati.mahanal.fmipa@um.ac.id, ORCID No: 0000-0001-5764-2184
[4] Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. **Email**: endang.suarsini.fmipa@um.ac.id, ORCID No: 0000-0003-0870-7791

opinions stipulated by experts in a particular field on a particular topic (Heller & Finley, 1992; Tan Sisman & Aksu, 2016). Students have owned conceptions before they come into the classroom; student conceptions are formed through experience and interactions with the surrounding physical and social environments (Gurcay & Gulbas, 2015; Lu, Bi, & Liu, 2018; Özmen, 2004).

Research has shown that misconceptions have an adverse effect on learning, especially on Biology students (Kalas, O'Neil, Pollock & Birol, 2013; Sesli & Kara, 2012). Misconceptions can interrupt the process of learning in Indonesia as students encounter problems in formulating productive dispositions (Yang & Sianturi, 2020). Misconceptions create a barrier to the restructuralization of knowledge and the development of students' ability to understand scientific concepts. Misconceptions make students resistant to changes; therefore, they stay in a relatively stable condition. Misconceptions form a new cognitive structure that is incompatible with scientific information that has been adopted by scientific communities (Hammer, 1996; Monteiro, Nóbrega, Abrantes, & Gomes, 2012; Gomez-Zwiep, 2008; Treagust, 2006). The broader scope of Biology and its complexity increases the likelihood of misconceptions or alternative concepts occurring in the classroom (Birks, Cant, James, Chung & Davis, 2013).

Human Anatomy and Physiology are two related compulsory subjects that should be learned by pre-service Biology teachers in university before conducting teaching practice in schools. Human Anatomy and Physiology courses conceptually contain complex materials that challenge students' comprehension of a lot of key concepts in Biology (Birks et al. 2013; Johnston et al. 2015; Smales, 2010). Research conducted by Hidayati, Zubaidah, Suarsini, & Praherdhiono (2020) shows that university students' content knowledge of Human Anatomy and Physiology materials correlates with their thinking ability. The comprehension of these materials is the key to understanding numerous life processes and the human body as a complex system (either at the cellular level, organ tissue, or system as a whole). Pre-service Biology teachers have to understand how the system works within themselves from the time they wake up until going to bed (Silverthorn, 2010). They need to avoid developing misconceptions about Human Anatomy and Physiology since these misconceptions may have a negative effect on their prospective students in the future. Biology teachers who develop misconceptions about Human Anatomy and Physiology may experience obstacles in teaching them to the students.

The concepts introduced in Human Anatomy and Physiology courses include the skeletal system, muscular system, integumentary system, nervous system, endocrine system, hemolymphatic system, cardiovascular system, respiratory system, digestive system, urinary system, and reproductive system (Sloane, 2016). Materials that are commonly covered in Human Anatomy and Physiology courses require a higher level of content knowledge. Misconceptions in Human Anatomy and Physiology have been developed by nursing students in the junior year (Badenhorst, Mamede, Hartman, & Schmidt, 2014). Research also reports student misconceptions about the digestive system (Cardak, 2015; Istikomayanti & Mitasari, 2017), and respiratory system (Alkhawaldeh & Al Olaimat, 2010). Misconception studies in Human Anatomy and Physiology have not been very popular among researchers in Indonesia. In fact, related studies are only limited to particular sub-materials. Therefore, there should be an effort to identify student misconceptions about more varied concepts using the diagnostic test.

The diagnostic test is a salient data collection instrument that can be used to recognize the flaws in student content knowledge. A variety of diagnostic tests such as interviews, open-ended tests, ordinary multiple-choice tests, and multiple-tier tests, have been used to identify student misconceptions. Among all of them, however, an interview test is considered the least effective for a large number of participants, a limited period, and a complicated data analysis (Jankvist & Niss, 2018; Tongchai, Sharma, Johnston, Arayathanitkul, & Soankwan, 2009). Open-ended test also lacks the adequacy of interpreting and evaluating the test-takers' answers (Kaltakci-Gurel, Eryilmaz, & McDermott, 2015). The ordinary multiple-choice test is expected to be able to deal with the shortcomings of the interview and open-ended tests. However, there is a possibility that during the test, the test taker may merely guess the answer and therefore their content knowledge cannot be adequately explored (Chang, Yeh, & Barufaldi, 2010). Considering these various test circumstances, a multiple-tier test (two-tier test) was developed (Lin, Yang, & Li, 2016; Treagust, 1988).

Unlike the ordinary multiple-choice test, a two-tier diagnostic test provides more space for the test taker to reason and interpret their answer. Two-tier diagnostic test also helps the teacher identify students' errors based on their answer to the test and thus is efficient for a larger population (Pan & Chou, 2015). Research shows that a two-tier diagnostic test has several limitations (Romine, Schaffer & Barrow, 2015). One of which is that it allows the test taker to predict the answer without sufficient information because there is no clear differentiation between answers that are based on a lack of knowledge and answers that are based on misconceptions (Caleon & Subramaniam, 2010; Peşman & Eryilmaz, 2010). For that reason, another tier that is Certainty of Response Index (CRI) needs to be added into the test. CRI can be placed in every test item to compensate for the diagnostic test weaknesses (Hasan, Bagayoko &

Kelley, 1999; Peşman & Eryilmaz, 2010). CRI uses the scale range of 0-5, where 0 signifies a lack of content knowledge (the answer is pure guessing). At the same time, 5 indicates full confidence in the truth, containing zero elements of guessing (Hasan et al. 1999). Certainty index or level of trust/confidence can evaluate and reveal student content knowledge and misconceptions about a concept (Taslidere, 2016).

A three-tier diagnostic test is considered highly capable of detecting errors in students' content knowledge more validly and reliably compared to an ordinary multiple-choice test or a two-tier diagnostic test (Karpudewan, Roth & Chandrakesan, 2015; Kiray, Aktan, Kaynar, Kilinc & Gorkemli, 2015). The result of a three-tier diagnostic test can help a teacher determine what should be improved in his/her students so that they can be free from false positive, false negative, misconceptions, and lack of knowledge (Arslan et al. 2012). In line with the results of the study conducted by Peşman and Eryılmaz (2010), a three-tier test can predict the percentage of false positive and false negative that can be used to calculate the test content validity. False-positive shows that the explanation/reasoning is incorrect (second tier), yet the answer is true (first tier). On the other hand, false negative indicates that the explanation/reasoning is correct (second tier), yet the answer is wrong (first tier) (Hestenes & Halloun, 1995). The first tier of a three-tier diagnostic test typically contains multiple-choice items; the second tier requires reasoning, while the third tier provides the level of trust for every answer found in the first and second-tier (Kaltakci-Gurel et al. 2015). A three-tier diagnostic test has been widely used as an evaluation tool to dismantle student misconceptions (Cheung & Yang, 2018; Gurcay & Gulbas, 2015; Prodjosantoso, Hertina & Irwanto, 2019). Particularly in Indonesia, there have not been many studies analyzing Biology students' misconceptions in Human Anatomy and Physiology courses using a three-tier diagnostic test.

Based on the explanations above, this study aimed to identify pre-service Biology teachers' misconceptions in Human Anatomy and Physiology courses using a three-tier diagnostic test. The results of this study are expected to be able to provide information on university students' misconceptions so that the learning process can be improved and applicable learning models can be developed.

Problem of Study

Previous research described about students misconceptions on human anatomy and physiology. However, research on the identification misconception of pre-service Biology teachers in Human Anatomy and Physiology course have not been done many especially in Indonesia, and research studies are only limited to particular sub-materials. The materials are actually broad and complex; there are many scientific terms that are difficult to understand by the pre-service Biology teachers. Misconceptions can influence the concept mastery of students in Junior and Senior High School level. If it is not handled properly, the result is going to be fatal since pre-service Biology teachers will teach at school. Therefore, it is important to identify their misunderstanding in human Anatomy and physiology so that they will not inherit the mistaken concepts to their students. To identify pre-service biology teachers' misconceptions, a diagnostic test, specifically a three-tier diagnostic test, is needed. The focuses of the research are:

- What is the level of the Biology Students' misconceptions in Human Anatomy and Physiology course?
- What is the description of the Biology students' concept understanding of Human Anatomy and Physiology?

Method

Research Design

This descriptive quantitative study aimed to investigate the level of pre-service Biology teachers' misconceptions and content knowledge in Human Anatomy and Physiology courses.

Participants

This study was conducted in Makassar, South Sulawesi, Indonesia. It involved 128 (39% male and 61% female) students from the Department of Biology Education at the Institute of Teacher Training and Educational Sciences (STKIP) Pembangunan Indonesia, Makassar. The participants were registered in the academic year of 2017/2018. Purposive sampling technique was used to select the sample. The sample was selected based on the following considerations; the first was because the participants were enrolled in Human Anatomy and Physiology courses in semester six, and the second was because the students reported problems in understanding the concepts introduced in the courses. The participants were aged between 20-23 years old.

Instrument

The instrument used to collect the data of this study was a three-tier diagnostic test. The test was constructed according to the materials taught in the Human Anatomy and Physiology courses that covered the skeletal, muscular, integumentary, nervous, endocrine, hemolymphatic, cardiovascular, respiratory, digestive, urinary, and reproductive

systems. Before its distribution, the three-tier diagnostic test had been validated by two senior lecturers, one holds a doctoral degree in Biology, and the other is a professor in the field of education. The validation test showed that the instrument was valid and thus was applicable. The point biserial correlation coefficient and the Cronbach alpha reliability coefficient of the three-tier diagnostic test were 0.426 (valid) and 0.794 (high reliability), respectively. The instrument also obtained a discrimination index of 0.224 (fair) and a difficulty index of 0.202 (difficult).

The three-tier diagnostic test contained 23 three-tier items. The first tier, called the content tier, aimed to test the test takers' content knowledge using true or false questions. The second tier or the reasoning tier aimed to obtain the test takers' explanations on the first tier answers. The second tier provided the students with five alternative answers, including one correct answer, three distractors, and one open-ended answer. The third tier aimed to clarify the level of the test-takers' confidence in their first and second tiers' answers (Peşman & Eryilmaz, 2010). The third tier was given in the form of the Certainty of Response Index (CRI) that used the 0-5 scale range. Low CRI or CRI <2.5 (CRI 0-2) indicates the element of guessing regardless of the true state of the answer. Low CRI indirectly reflects the test takers' lack of knowledge in answering the test questions. An example of the three-tier diagnostic test item used is:
The texture of the earlobe bone in humans is different from the femur.

a. True
b. False
} First tier

Reason:
1) The earlobe is made up of cartilage bone while the femur is made up of compact bone;
2) The earlobe is not categorized as bone;
3) The earlobe bone does not experience ossification.
4) The earlobe is a sesamoid bone.
5) ……..
} Second

Confidence level:
0 1 2 3 4 5
} Third tier

Conversely, high CRI or CRI >2.5 (CRI 3-5) suggests the test' takers' high confidence in the correctness of the answer. The students who both answered correctly and achieved high CRI also had high confidence in the accuracy of the answer (Hasan et al. 1999). However, an incorrect answer would indicate an error in the students' content knowledge, suggesting a misconception about a concept (Romine et al. 2015).

Data Analysis

The data were analyzed descriptively and quantitatively using the following procedures:

- Examined the students' answers based on the answer key.
- Determined the score of each test item based on the guidelines presented in Figure1.
- Set the category for the students' responses based on the categorization of scores presented in Table 1.
- Calculate the percentage of each response category (Table 1). Lucky guess was categorized into a lack of knowledge, while false positive and false negatives were categorized into misconceptions.
- Calculate the number of students who experienced misconceptions into percentage and categorize them into three levels, which are high (61%-100%), medium (31%-60%), and low (0%-30%).

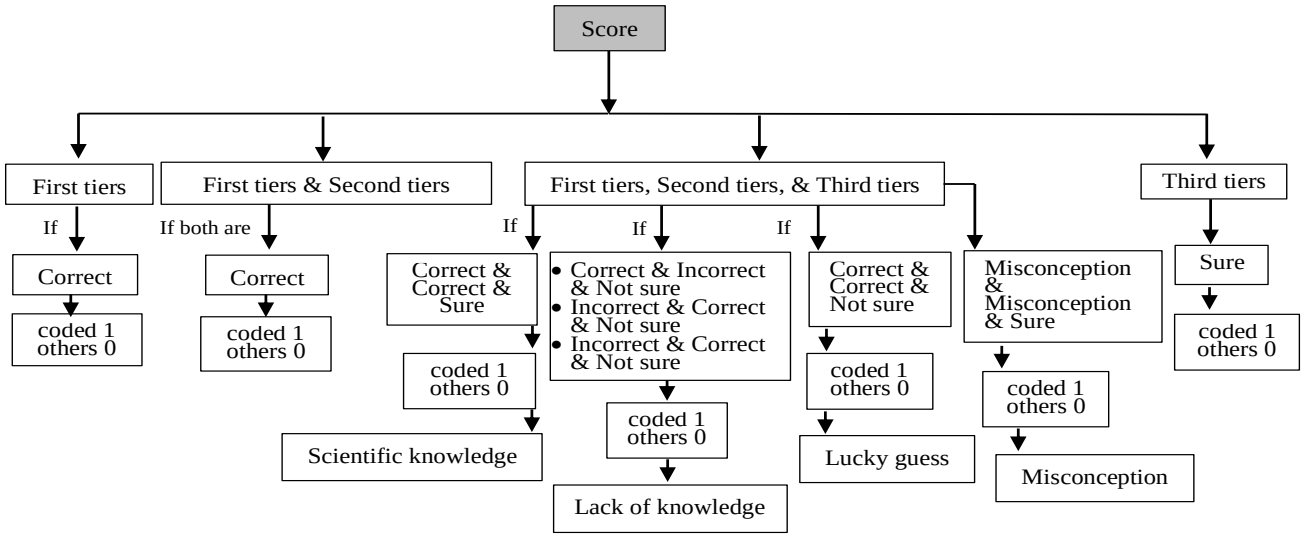

Figure 1.
Scoring Each Item about Three-Tier Diagnostic Test

Table. 1
All Possibilities of Responses

First-tier	Second-tier	Third-tier	Categories
Correct	Correct	>2.5	Scientific knowledge
Correct	Incorrect	>2.5	Misconception (false positive)
Incorrect	Correct	>2.5	Misconception (false negative)
Incorrect	Incorrect	>2.5	Misconception
Correct	Correct	<2.5	Lucky guess
Correct	Incorrect	<2.5	Lack of knowledge
Incorrect	Correct	<2.5	Lack of knowledge
Incorrect	Incorrect	<2.5	Lack of knowledge

Source: Arslan et al. 2012

Results

The results of the analysis on the students' misconceptions about various topics in Human Anatomy and Physiology can be seen in Table 2.

Table 2.
Percentage of Student Responses about Various Topics in Human Anatomy and Physiology

Sub-Material	Test Item	% *Scientific Knowledge*	% *Misconception*	% *Lack of Knowledge*
Skeletal system	3	21.09	58.59	20.31
	4	26.56	57.03	16.41
Mean (%)		**23.83**	**57.81**	**18.36**
Muscular system	5	26.56	52.34	21.09
	6	27.34	52.34	20.31
Mean (%)		**26.95**	**52.34**	**20.70**
Integumentary system	1	21.88	55.47	22.66
	2	18.75	55.47	25.78
Mean (%)		**20.31**	**55.47**	**24.22**
Nervous system	7	**32.03**	50.78	17.19
	8	29.69	46.88	23.44
	9	26.56	55.47	17.97
Mean (%)		**29.43**	**51.04**	**19.53**

Endocrine system	10	24.22	54.69	21.09
	11	26.56	54.69	18.75
Mean (%)		**25.39**	**54.69**	**19.92**
Hemolymphatic system	14	16.41	64.84	18.75
	15	14.84	67.19	17.97
Mean (%)		**15.63**	**66.02**	**18.36**
Cardiovascular system	12	17.97	63.28	18.75
	13	24.22	62.50	13.28
Mean (%)		**21.09**	**62.89**	**16.02**
Respiratory system	16	**11.72**	70.31	17.97
	17	17.97	67.19	14.84
Mean (%)		**14.84**	**68.75**	**16.41**
Digestive system	18	12.50	71.88	15.63
	19	12.50	68.75	18.75
Mean (%)		**12.50**	**70.31**	**17.19**
Urinary system	20	15.63	66.41	17.97
	21	12.50	75.00	12.50
Mean (%)		**14.06**	**70.70**	**15.23**
Reproductive system	22	14.06	71.88	14.06
	23	14.06	71.88	14.06
Mean (%)		**14.06**	**71.88**	**14.06**
Total Mean (%)		**20.24**	**61.51**	**18.24**

Table 2 shows that 24.24% of students are in the "scientific knowledge" category, 61.51% are in the "misconception" category, and 18.24% are in the "lack of knowledge" category. Among the three categories, misconception category reported the highest percentage, so it can be inferred that the majority of the students developed a lot of misconceptions about materials taught in Human Anatomy and Physiology courses.

The highest percentage in the scientific knowledge category was found in nervous system sub-materials (29.43%), while the lowest was observed in the integumentary system sub-materials (12.50%). The highest percentage in the lack of knowledge category was observed in the integumentary system sub-materials (24.22%), while the lowest was found in reproductive system sub-materials (14.06%). Overall, the highest percentage of student misconceptions was about the reproductive system (71.88), while the lowest was about the nervous system (51.04%). The percentages of student numbers who answered correctly in the first tier and second-tier tests are presented in detail in Figure 2.

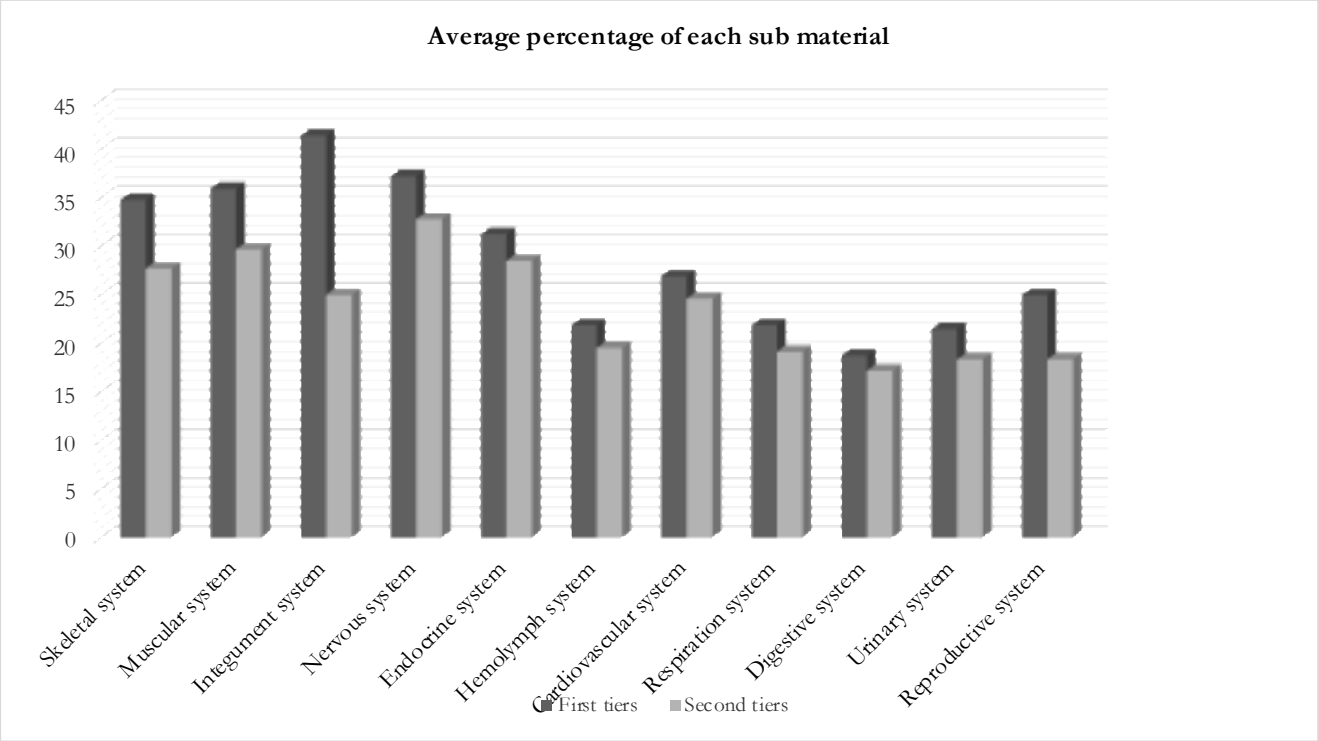

Figure 2.

Mean Diagram Percentage of Correct Response of Students in Each Sub-Material Human Anatomy and Physiology

Figure 2 demonstrates the number of students (in percentage) who answered correctly in the first tier. This number is higher than the number of students who answered correctly in the second tier. The highest percentage of the correct answers in the first tier test was related to the integumentary system (41.41%), while the lowest was related to the digestive system (18.75%). In the second tier test, the highest percentage of the correct answers was related to the nervous system (32.81%), and the lowest was related to the digestive system (17.19%).

The three-tier test was used to measure the participants' misconceptions in Human Anatomy and Physiology courses. Each item of the test contained three questions. Data analysis showed that the participants provided different answers to every question. The examples of the students' answers based on the test category can be seen in Table 3.

Table 3.

Examples of Students' Responses to Three-Tier Diagnostic Test

Number of Participant	Questions and Answers in Bahasa Indonesia	Questions and Answers in English	Category
39	7. Skema gerak refleks yaitu rangsang → reseptor → neuron sensorik → serebelum→ neuron motorik → efektor. a. Benar b. Salah **Alasan:** 1) Gerak refleks berjalan sangat cepat melalui lengkung refleks dan memerlukan kontrol dari serebelum. 2) Impuls melalui lengkung refleks, yaitu reseptor diteruskan oleh saraf sensorik ke pusat saraf diterima oleh konektor tanpa diolah di dalam otak dikirim ke saraf motorik terakhir ke efektor. 3) Reseptor penerima rangsang diteruskan ke dendrit diolah di serebelum kemudian diteruskan ke neuron motorik. 4) Gerak refleks memerlukan kontrol dari otak yang berfungsi sebagai sistem saraf pusat. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	7. The scheme of a reflex: a stimulus -> receptor->sensory neuron->cerebellum->motor neuron --> effector a. True b. False **Reason:** 1) A reflex moves rapidly through a reflex arc and requires control from the cerebellum. 2) An impulse is passed through a reflex arc, which acts as the receptor, and continued to the spinal cord by the sensory neuron, received by a connector; without being processed in the brain, it is sent to the motor neuron and passed to the effector. 3) The receptor receives the stimulus and passed to the dendrite, processed in the cerebellum before it is sent to the motor neuron. 4) A reflex requires control from part of the brain that functions as the central nervous system.	Scientific knowledge

	Correct Statement: An impulse is passed through a reflex arc, which acts as the receptor, and continued to the spinal cord by the sensory neuron, received by a connector; without being processed in the brain, it is sent to the motor neuron and passed to the effector. **(B 2)**		
2	16. Inspirasi terjadi jika tekanan udara dalam paru-paru lebih tinggi dari udara atmosfer sehingga udara dapat masuk ke dalam paru-paru. a. Benar b. Salah **Alasan:** 1) Inspirasi terjadi saat otot antar tulang rusuk berkontraksi, volume rongga dada meningkat dan paru-paru mengembang, tekanan udara lebih rendah dari udara atmosfer, sehingga udara dapat masuk dalam paru-paru. 2) Saat inspirasi, otot antar tulang rusuk berelaksasi, volume rongga perut meningkat dan paru-paru mengembang, sehingga udara dapat masuk ke dalam paru-paru. 3) Inspirasi terjadi jika otot diafragma berelaksasi, sehingga paru-paru dapat mengembang, dan udara dapat masuk dalam paru-paru. 4) Inspirasi terjadi saat otot paru-paru dalam keadaan kontrkasi dan relaksasi, sehingga volume rongga perut meningkat dan udara masuk ke dalam paru-paru. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	16. Inspiration occurs when the intrapulmonary pressure is higher than that in the atmosphere, allowing the air to enter the lungs. a. True b. False **Reason:** 1) Inspiration occurs when the intercostal muscles experience a contraction, the volume of the chest cavity increases, and the lung volume expands, the intrapulmonary pressure is lower than the air pressure in the atmosphere, allowing the air to enter the lungs. 2) During inspiration, the intercostal muscles experience a relaxation, the volume of the chest cavity increases and the lung volume expands, allowing the air to enter the lungs. 3) Inspiration occurs when the diaphragm relaxes, expanding the volume of the lungs and allowing the air to enter the lungs. 4) Inspiration occurs when the respiration muscles are in the contraction and relaxation state, the volume of the abdominal cavity increases, allowing the air to enter the lungs.	Misconception
	Correct statement: Inspiration occurs when the intercostal muscles experience a contraction, the volume of the chest cavity increases, and the lung volume expands, the intrapulmonary pressure is lower than the air pressure in the atmosphere, allowing the air to enter the lungs. **(B 1)**		
40	3. Tekstur tulang pada daun telinga berbeda dengan tulang paha tubuh manusia. a. Benar b. Salah **Alasan:** 1) Tulang daun telinga tersusun atas tulang rawan, sedangkan tulang paha tersusun atas tulang kompak. 2) Daun telinga tidak termasuk tulang. 3) Tulang daun telinga tidak mengalami osifikasi. 4) Tulang daun telinga termasuk jenis tulang sesamoid. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	3. The texture of the earlobe bone in humans is different from the femur. c. True d. False **Reason:** 6) The earlobe is made up of cartilage bone while the femur is made up of compact bone; 7) The earlobe is not categorized as bone; 8) The earlobe bone does not experience ossification. 9) The earlobe is a sesamoid bone.	Misconception (false positive)
	Correct Statement: The texture of the earlobe bone in humans is different from the femur because the earlobe is made up of cartilage bone while the femur is made up of compact bone. **(A 1)**		

97	23. Testis memproduksi sperma sejak manusia berumur 0 bulan, namun pematangan sperma terjadi saat pubertas. a. Benar b. Salah **Alasan:** 1) Saat masih 0 bulan masih berupa spermatogonia, kemudian mengalami meiosis menjadi sperma saat pubertas. 2) Saat 0 bulan yang terbentuk adalah spermatid, menjelang pubertas spermatid berkembang menjadi sperma yang matang. 3) Gametogenesis pada laki-laki dimulai sejak di dalam rahim membentuk sel sperma dan berlangsung sepanjang hidup. 4) Sperma terbentuk saat dimulainya kehidupan pada manusia, saat dewasa sperma berdiferensiasi menjadi spermatosit primer yang matang. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	23. Sperm cells have been produced in the testicles since the age of 0, but they become fertile upon reaching puberty. a. True b. False **Reason:** 1) Since the age of 0, sperm cells exist in the form of spermatogonia, then when a boy reaches the puberty age, spermatogonia begin the process of meiosis to become mature sperm cells. 2) At the age of 0, sperm cells exist in the form of spermatids, and upon reaching puberty, spermatids develop into mature sperm cells. 3) Gametogenesis in boys/men begins since they are conceived in the womb. The process that lasts a lifetime continuously produces sperm cells. 4) Sperm cells have been formed since the beginning of life in humans; when boys reach maturity, sperm cells are differentiated into mature primary spermatocytes.	Misconception (false negative)
	Correct Statement: Since the age of 0, sperm cells exist in the form of spermatogonia, then when a boy reaches the puberty age, spermatogonia begin the process of meiosis to become mature sperm cells. **(B 1)**		
15	1. Kulit merupakan lapisan atau jaringan yang menutupi seluruh tubuh dan mempunyai ketebalan yang sama pada permukaan tubuh manusia. a. Benar b. Salah **Alasan:** 1) Kulit terdiri dari epidermis, dermis, dan hipodermis 2) Kulit sekitar mata lebih tipis, kulit telapak tangan dan telapak kaki lebih tebal. 3) Kulit tumbuh dari dua jaringan yaitu jaringan epitel dan jaringan pengikat. 4) Derivat kulit contohnya kuku, kulit yang mengeras lebih tebal dari kulit yang lain. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	1. Skin is a layer or a tissue that covers the human body. The whole body is covered by the same skin thickness. a. True b. False **Reason**: 1) The skin consists of epidermis, dermis, and hypodermis. 2) The skin around the eyes is thinner, the skin on the palms and foot is thicker. 3) The skin grows from two types of tissues, epithelial tissue, and connective tissue. 4) One of the examples of skin derivatives is nails; hardened skin is much thicker than the other types of skin.	Lucky guess
	Correct Statement: Skin is a layer or a tissue that covers the human body. There are variations in the thickness of the skin. The skin on foot, for example, is much thicker than the skin around the eyes. **(B 2)**		
120	18. Makanan yang tidak diserap oleh usus halus akan diserap oleh usus besar. a. Benar b. Salah **Alasan:** 1) Usus besar tidak mensekresi enzim pencernaan dan hanya mengekskresi zat sisa dalam bentuk feses. 2) Usus besar mengeluarkan hormon pencernaan dan mengabsorpsi kembali makanan yang tidak terserap di usus halus. 3) Usus besar mensekresi empedu dan menyerap nutrien lebih lanjut. 4) Usus besar menyimpan sisa makanan sebelum defekasi dan melakukan detoksifikasi. 5) ..... **Tingkat Keyakinan:** 0 1 2 3 4 5	18. Food that is not absorbed by the intestine will be absorbed by the colon. a. True b. False **Reason**: 1) The colon cannot secrete digestive enzymes and is only able to excrete residual substances in the form of feces. 2) The colon produces digestive hormones and re-absorb food that cannot be absorbed by the intestine. 3) The colon secretes bile and absorbs nutrients at an advanced level. 4) The colon stores the residual food before defecation and detoxification.	Lack of knowledge
	Correct Statement: Food cannot be absorbed by the colon because the colon does not secrete digestive enzymes and is only able to excrete residual substances in the form of feces. **(B 1)**		

Table 3 shows that student/participant number 39 has scientific knowledge since he was able to answer correctly on the first tier and second-tier tests with a high level of confidence (CRI 5). The misconception is given to the participants who answered incorrectly in either one of the tiers or both tiers at a high level of confidence (CRI >2.5).

The examples of misconception answers are numbers 16, 3, and 23. The participants who were able to answer correctly at both tiers, but had a low level of confidence (CRI <2.5) such as in item no. 1 are categorized into the lucky guess and lack of knowledge categories. Student/participant number 120 experienced a lack of knowledge because the answer to one of the tiers or both tiers was incorrect, and the level of confidence was low (CRI <2.5).

Discussion

The results of the study suggest that the pre-service Biology teachers develop a lot of misconceptions in Human Anatomy and Physiology courses (61.51% or high category). This figure shows that the materials taught in the courses are quite complex. The previous related studies have revealed the causes of why these misconceptions occur in the classroom and why the failure rates are high. Human Anatomy and Physiology contain complex and abstract concepts that are related to all systems working in the human body (Brown, Bowmar, White & Power, 2016; Johnston et al. 2015). There are also numerous scientific terms taught in the courses, and the materials are compact. Human Anatomy and Physiology courses require the students to understand and accurately analyze human body and anatomy, the mechanical, physical, bioelectrical, and biochemical functions of the human body, as well as specifically related diseases (Standing, 2005; Barrett, Barman, Brooks & Yuan, 2016). Therefore, the lack of interactive learning methods implemented in the classroom and the developed habit of memorizing information may result in weakening the students' analytical ability (Badenhorst, Hartman & Mamede, 2016). Also, the students' negative learning experience in previous Human Anatomy and Physiology courses can potentially create a particular "phobia" to the materials (Craft, Hudson, Plenderleith, Wirihana & Gordon, 2013). Time constraints also make it impossible to cover the discussion of the whole contents in the courses (McVicar, Andrew & Kemble, 2014).

The materials covered in Human Anatomy and Physiology courses are the skeletal system, muscular system, integumentary system, nervous system, endocrine system, hemolymphatic system, cardiovascular system, respiratory system, digestive system, urinary system, and reproductive system (Sloane, 2016). The findings from this study show that the participants develop a lot of misconceptions about the reproductive system. This may be due to the difficulty in visualizing and understanding the oogenesis and gametogenesis processes. The previous related research has also revealed that there are a large number of students who experience misconceptions in physiology sub-concepts, including women and men reproduction systems and fertilization (Taufiq, Sriyati, & Priyandonko, 2017). The students should deal with the conflict that arises due to the discrepancy between their conceptions and the scientific conceptions. Misconceptions about the reproductive system are often developed because the reproduction system is abstract; it is difficult to form a mental image of mitosis and meiosis (Kalas et al. 2013; Lewis & Kattmann 2004; Sesli & Kara, 2012). On the contrary, university students find the nervous system less troublesome. The results of the test showed that the percentage of the students' correct answers to nervous system questions was higher than that of the others' materials. This may be due to the fact that the students had acquired knowledge of the mechanism of a reflex and the difference between the sympathetic nervous system and the parasympathetic nervous system. According to Sloane (2016), the application of appropriate learning can motivate students to understand the nervous system material more quickly.

The students' responses to the test questions were used to classify them into several categories. In Table 3, for example, participant number 2 belongs to the misconception category, participant number 40 belongs to the false-positive category, and participant number 97 belongs to the false negative category. These students failed to explain the concept correctly and thus provided an incorrect statement to the answer, yet the level of confidence was high. Participant number 2 believed in an incorrect concept that inspiration occurs when the intrapulmonary pressure is higher than the air pressure in the atmosphere. Even so, the participant had a high level of confidence. This high level of confidence may affect one's response to the acquisition of new information. Similarly, Caleon & Subramaniam (2010) argue that overconfidence in a concept can impede the reconceptualization of learning at an advanced level. Overconfidence makes students believe that their understanding of a concept is correct, while in fact, it is not. Therefore, the students need to promote the awareness of the inaccuracy of their judgment of a concept.

Furthermore, it was also discovered that 18.24% of the participants in this study experienced a lack of knowledge or lack of concept mastery. The students' lack of knowledge may result from an imperfect learning process in which the students find difficulty following the lesson or paying full attention to the teacher. Research shows that knowledge acquisition is facilitated by a favorable learning process (San Pedro, Baker, & Heffernan, 2017). The learning process that fails to help students deal with their learning difficulties will slow down knowledge construction (Bowers, 2016). If students are constantly faced with many difficulties in learning, the track record is low (Teo & Goh, 2019). The

difficulties faced by the students are normally associated with abstract information that requires them to elaborate on answers that are relevant to the materials being learned.

Instead of misconceptions and lack of knowledge, 20.24% of the participants of this study were able to grasp the concepts being learned in the Human Anatomy and Physiology courses (scientific knowledge). The students' positive learning experience in the previous Human Anatomy and Physiology courses has a significant contribution to the scientific knowledge they possess. In line with an earlier study, learners' positive learning experience has a significant effect on their content knowledge and learning achievement in science classes (Faisal & Martin, 2019). Learning that is set within a real-life context can provide an authentic and meaningful experience to the students, so the concepts learned in the classroom will be tightly embedded in the students and thus unforgettable. Variations in students' learning achievement have a positive correlation with the quality of previous learning experience. In-depth learning produces a high quality of learning experience and vice versa (Matthew, Taylor, & Ellis, 2012).

Participant number 39 is one of the examples of students who have good scientific knowledge. Participant number 39 was able to determine the correct scheme of a reflex with a high level of confidence (CRI 5). Scientific knowledge is the result of scientific processes, observation, data collection, and accurate conclusion drawing (The Role of Scientific Knowledge in Research & Peer Review, 2016). Scientific knowledge is empirical and is obtained through a systematic study. It can create innovations in knowledge with a more comprehensive range based on the rules stipulated by scientists (National Research Council, 2007).

Besides classifying misconceptions in the Human Anatomy and Physiology courses, this study also sought to examine the students' answer to every question at every tier (Figure 2). The percentage of correct answers in the first tier was higher than that of the second tier because the students were already capable of distinguishing the correct concept from the incorrect one. However, the students failed to provide the correct statement to the answer at the second tier. This suggests that Biology students are unable to comprehend the concepts in Human Anatomy and Physiology. Based on the study conducted by Pascua & Chang (2015), partial understanding refers to the condition when students can only answer correctly at the first tier but are unable to provide the correct reasoning to the answer at the second tier. Other research findings have also revealed that the tendency of students to memorize information results makes it difficult to understand and synthesize essential concepts in Human Anatomy and Physiology (Badenhorst et al. 2016; Johnston et al. 2015).

There are a lot of misconceptions developed among university students in Human Anatomy and Physiology courses. Through a three-tier diagnostic test, misconceptions, and the level of students' content knowledge can be detected. A three-tier diagnostic test can also reveal the number of students who have misconceptions, understand the concepts, or fail to comprehend the concepts. University students can construct a causal relationship and internalize concepts to achieve scientific truth. A three-tier diagnostic test can help a teacher identify students' misconceptions and treat them accordingly (Karpudewan et al. 2014). Also, a three-tier diagnostic test can train students' reasoning ability and fix concept misunderstanding among students who have a high level of confidence (Cheung & Yang, 2018).

The results of this study indicate that pre-service Biology teachers have developed a lot of Human Anatomy and Physiology misconceptions. Thus, the lecturer needs to design a learning model to anticipate these misconceptions. One of the examples of the learning models applicable to this situation is an active and meaningful learning model. An active and meaningful learning model can provide a high-quality learning experience that can facilitate students' concepts of understanding, reasoning, and knowledge actualization. Furthermore, it is also necessary to conduct a more in-depth study to identify university students' misconceptions in various subjects. The researcher of the research needs to clarify the reason why the students select the answer. Besides, the researcher also needs to conduct a clinical interview to review the students' alternative ideas and articulate them in questions. The improvement of quality assessment tools to diagnose misconceptions is paramount.

Conclusion

A three-tier diagnostic test can be used to identify pre-service Biology teachers' scientific knowledge, misconceptions, and lack of knowledge in Human Anatomy and Physiology courses. The results of this study showed that 61.51% of the participants developed misconceptions in Human Anatomy and Physiology courses. The highest percentage of misconceptions (71.88%) was related to reproductive system sub-materials, while the lowest (51.04%) was found in nervous system sub-materials. It can be concluded that the students' misconceptions are in the high category. Therefore, an active and meaningful learning model needs to develop as a remedy for the students' misconceptions. In addition, future research needs to integrate a three-tier diagnostic test into different types of a diagnostic test.

Acknowledgement

Announcement of thanks to the Republic of Indonesia Ministry of Research, Technology and Higher Education and Education Fund Management Institution (LPDP) for facilitating this research.

Biodata of the Author

Andi Andariana was born in Bone, Indonesia. She completed her Senior High School at Tellusiattinge 1 State High School in 2007. He graduated from the Department of Biological Sciences, Makassar State University in 2011, then continued his master's program in the department of biology education at Makassar State University in 2012-2014. Currently, she is continuing her doctoral program in biology education at postgraduate state Universitas Negeri Malang. She is a lecturer in STKIP Pembangunan Indonesia, South Sulawesi Province, Indonesia. His research focuses on biology teacher education and teaching and learning biology. **Affiliation:** Postgraduate of Biology Education Universitas Negeri Malang, Biology Education Program, and Biology education at the STKIP Pembangunan Indonesia, South Sulawesi Province, Indonesia. **E-mail:** andi.andariana@stkippi.ac.id **Phone:** (+62) 85259019878 **Orcid No:** 0000-0003-3876-6530 **Scopus ID:** 57211661707 **WoS Researcher ID:** -

Prof. Dr. Siti Zubaidah, S. Pd., M. Pd, was born in Malang, East Java, Indonesia. She is a professor at Universitas Negeri Malang, Indonesia. She completed her Bachelor's degree and master's degree in Biology Education at the Institute of Teacher Training and Education (IKIP) Malang. She received her doctoral degree in Agriculture/Biology of Plant Diseases at Universitas Brawijaya Malang, Indonesia. She is interested in Molecular Biological Analysis Techniques, Genetics, and Biology Learning Model Development, Teaching and Learning, Educational Evaluation, Metacognition, and Critical Thinking. **Affiliation:** Department of Biology, Universitas Negeri Malang, Indonesia **E-mail:** siti.zubaidah.fmipa@um.ac.id **Phone:** (+62) 81334435234 **Orcid No:** 0000-0002-0718-6392 **Scopus ID:** 57193818701 **WoS Researcher ID**: -

Prof. Dr. Susriyati Mahanal, M.Pd, born in Banyuwangi, East Java, Indonesia, on August 10, 1956, is a professor at Universitas Negeri Malang, Indonesia. She received her Bachelor's degree in Biology Education in 1978, a Master's degree in Education in 1998 from IKIP Malang, and a Doctoral degree in Biology in 2007 from the Universitas Negeri Malang. Since 1990, she has been a lecturer at the Universitas Negeri Malang. **Affiliation:** Departement of Biology, Universitas Negeri Malang, Indonesia **E-mail:** susriyati.mahanal.fmipa@um.ac.id **Phone:** (+62) 82143303052 **Orcid No:** 0000-0001-5764-2184 **Scopus ID:** 57193096117 **WoS Researcher ID:** -

Dr. Endang Suarsini, M.S. was born in April 1953. She is a doctor from Universitas Negeri Malang, Indonesia. She got the master of Basic Medical Sciences, Universitas Indonesia. Mainly engaged in microbiology, teaching, and learning research. She has participated in many national and international conferences. The results of her research have also been published in a reputable journal. **Affiliation:** Departement of Biology, Universitas Negeri Malang, Indonesia **E-mail:** endang.suarsini.fmipa@um.ac.id **Phone:** (+62) 82140136657 **Orcid No:** 0000-0003-0870-7791 **Scopus ID:** 53980615000 **WoS Researcher ID:** -

References

Alkhawaldeh, SA., & Al Olaimat, AM. (2010). The contribution of conceptual change texts accompanied by concept mapping to eleventh-grade students understanding of cellular respiration concepts. *Journal of Science Education and Technology, 19,* 115–125. https://doi.org/10.1007/s10956-009-9185-z

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A Three-Tier Diagnostic Test to Assess Pre-Service Teachers' Misconceptions about Global Warming, Greenhouse Effect, Ozone Layer Depletion, and Acid Rain. *International Journal of Science Education, 34*(11), 1667–1686. https://doi.org/10.1080/09500693.2012.680618

Badenhorst, E., Hartman, N., & Mamede, S. (2016). How Biomedical Misconceptions May Arise and Affect Medical Students' Learning: A Review of Theoretical Perspectives and Empirical Evidence. *Health Professions Education, 2*(1), 10–17. https://doi.org/10.1016/j.hpe.2016.01.005

Badenhorst, E., Mamede, S., Hartman, N., & Schmidt, H. G. (2014). Exploring lecturers' views of first-year health science students' misconceptions in biomedical domains. *Advances in Health Sciences Education, 20*(2), 403–420. https://doi.org/10.1007/s10459-014-9535-3

Barrett, K, E., Barman, S, M., Brooks, H, L., & Yuan, J. (2016). *Ganong's: Review of medical physiology* (26th ed.). New York: McGraw-Hill Education.

Birks, M., Cant, R., James, A., Chung, C., & Davis, J. (2013). The use of physical assessment skills by registered nurses in Australia: Issues for nursing education. *Collegian, 20*(1), 27–33. https://doi.org/10.1016/j.colegn.2012.02.004

Bowers, J. S. (2016). The practical and principled problems with educational neuroscience. Psychological Review, 123(5), 600-612. http://dx.doi.org/10.1037/rev0000025

Brown, S., Bowmar, A., White, S., & Power, N. (2016). Evaluation of an instrument to measure undergraduate nursing student engagement in an introductory Human anatomy and physiology course. *Collegian, 24*(5), 491–497. https://doi.org/10.1016/j.colegn.2016.09.006

Caleon, I., & Subramaniam, R. (2010). Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves. *International Journal of Science Education, 32*(7), 939–961. https://doi.org/10.1080/09500690902890130

Cardak, O. (2015). Student science teachers' ideas of the digestive system. *Journal of Education and Training Studies, 3*(5), 127-133. https://doi.org/10.11114/jets.v3i5.912

Chang, C. Y., Yeh, T. K., & Barufaldi, J. P. (2010). The positive and negative effects of science concept tests on student conceptual understanding. *International Journal of Science Education, 32*(2), 265–282. https://doi.org/10.1080/09500690802650055

Cheung, K. L., & Yang, D. C. (2018). Performance of sixth graders in Hong Kong on a number sense three-tier test. *Educational Studies, 46*(1), 39–55. https://doi.org/10.1080/03055698.2018.1516631

Craft, J., Hudson, P., Plenderleith, M., Wirihana, L., Gordon, C., (2013). Commencing nursing students' perceptions and anxiety of bioscience. *Nurse Education Today, 33*(11), 1399-1405. http://dx.doi.org/10.1016/j.nedt.2012.10.020

Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics, 72*(1), 98–115. https://doi.org/10.1119/1.1614813

Faisal & Martin, S. N. (2019). Science education in Indonesia: past, present, and future. *Asia-Pacific Science Education, 5*(4), 1-29. https://doi.org/10.1186/s41029-019-0032-0

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education. *Journal of Science Teacher Education, 19*(5), 437–454. https://doi.org/10.1007/s10972-008-9102-y

Gurcay, D., & Gulbas, E. (2015). Development of three-tier heat, temperature and internal energy diagnostic test. *Research in Science and Technological Education, 33*(2), 197–217. https://doi.org/10.1080/02635143.2015.1018154

Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research. *American Journal of Physics, 64*(10), 1316–1325. https://doi.org/10.1119/1.18376

Hasan, S., Bagayoko, D., & Kelley, E. L. (1999). Misconceptions and the certainty of response index (CRI). *Physics Education, 34*(5), 294–299. https://doi.org/10.1088/0031-9120/34/5/304

Hebe, H. (2020). In-service teachers' knowledge and misconceptions of global warming and ozone layer depletion: A case study. *Journal for the Education of Gifted Young Scientists, 8*(1), 133–149. https://doi.org/10.17478/jegys.618491

Heller, P. M., & Finley, F. N. (1992). Variable uses of alternative conceptions: A case study in current electricity. *Journal of Research in Science Teaching, 29*(3), 259–275. https://doi.org/10.1002/tea.3660290306

Hestenes, D., and I. Halloun. 1995. "Interpreting the Force Concept Inventory. *Physics Teacher, 33,* 502–506.

Hidayati, N., Zubaidah, S., Suarsini, E., & Praherdhiono, H. (2019). The integrated PBL-DMM: A learning model to enhance student creativity. *Pedagogika. 135*(3). 163-184. https://10.15823/p.2019.135.9

Istikomayanti, Y., & Mitasari, Z. (2017). Student's misconception of digestive system materials in mts eight grade of malang city and the role of teacher's pedadogic competency in MTs. *Jurnal Pendidikan Biologi Indonesia, 3*(2), 103-113.

Jankvist, U. T., & Niss, M. (2018). Counteracting destructive student misconceptions of mathematics. *Education Sciences, 8*(2), 1-17. https://doi.org/10.3390/educsci8020053

Johnston, A. N. B., Hamill, J., Barton, M. J., Baldwin, S., Percival, J., Williams-Pritchard, G., Salvage-Jones, J., & Todorovic, M. (2015). Student learning styles in anatomy and physiology courses: Meeting the needs of nursing students. *Nurse Education in Practice, 15*(6), 415–420. https://doi.org/10.1016/j.nepr.2015.05.001

Kalas, P., O'Neill, A., Pollock, C., & Birol, G. (2013). Development of a meiosis concept inventory. CBE Life Sciences Education, 12(4), 655–664. https://doi.org/10.1187/cbe.12-10-0174

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2016). Identifying pre-service physics teachers' misconceptions and conceptual difficulties about geometrical optics. *European Journal of Physics, 37*(4), 1–30. https://doi.org/10.1088/0143-0807/37/4/045705

Karpudewan, M., Roth, W. M., & Chandrakesan, K. (2014). Remediating misconception on climate change among secondary school students in Malaysia. *Environmental Education Research, 21*(4), 631–648. https://doi.org/10.1080/13504622.2014.891004

Kiray, S. A., Aktan, F., Kaynar, H., Kilinc, S., & Gorkemli, T. (2015). A descriptive study of pre-service science teachers' misconceptions about sinking-floating. *Asia-Pacific Forum on Science Learning and Teaching, 16*(2).

Lewis, J., & Kattmann, U. (2014). Traits, genes, particles and information: Re-visiting students' understandings of genetics. *International Journal of Science Education, 26*(2), 195–206. https://doi.org/10.1080/0950069032000072782

Lin, Y. C., Yang, D. C., & Li, M. N. (2016). Diagnosing students' misconceptions in number sense via a web-based two-tier test. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(1), 41–55. https://doi.org/10.12973/eurasia.2016.1420a

Lu, S., Bi, H., & Liu, X. (2018). The effects of explanation-driven inquiry on students' conceptual understanding of redox. *International Journal of Science Education, 40*(15), 1857–1873. https://doi.org/10.1080/09500693.2018.1513670

Matthew, S. M., Taylor, R. M., & Ellis, R. A. (2012). Relationships between students' experiences of learning in an undergraduate internship programme and new graduates' experiences of professional practice. *Higher Education, 64*(4), 529–542. https://doi.org/10.1007/s10734-012-9509-4

McVicar, A., Andrew, S., & Kemble, R. (2014). Biosciences within the pre-registration (pre-requisite) curriculum: An integrative literature review of curriculum interventions 1990-2012. *Nurse Education Today, 34*(4), 560-568. http://dx.doi.org/10.1016/j.nedt.2013.08.012

Monteiro, A., Nóbrega, C., Abrantes, I., & Gomes, C. (2012). Diagnosing Portuguese Students' Misconceptions about the Mineral Concept. *International Journal of Science Education, 34*(17), 2705–2726. https://doi.org/10.1080/09500693.2012.731617

National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8. Washingt*on, DC: The National Academies Press. https://doi.org/10.17226/11625

Odom, A. L., & Barrow, L. H. (1995). Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction. *Journal of Research in Science Teaching, 32*(1), 45–61. https://doi.org/10.1002/tea.3660320106

Özmen, H. (2004). Some Student Misconceptions in Chemistry: A Literature Review of Chemical Bonding. *Journal of Science Education and Technology, 13*(2), 147–159. https://doi.org/10.1023/b:jost.0000031255.92943.6d

Pan, S. J. A., & Chou, C. (2015). Using a Two-Tier Test to Examine Taiwanese Graduate Students' Misunderstanding of Responsible Conduct of Research. *Ethics and Behavior, 25*(6), 500–527. https://doi.org/10.1080/10508422.2014.987921

Pascua, L., & Chang, C. H. (2015). Using intervention-oriented evaluation to diagnose and correct students' persistent climate change misconceptions: A Singapore case study. *Evaluation and Program Planning, 52,* 70–77. https://doi.org/10.1016/j.evalprogplan.2015.04.001

Peşman, H., & Eryilmaz, A. (2010). Development of a three-tier test to assess misconceptions about simple electric circuits. *Journal of Educational Research, 103*(3), 208–222. https://doi.org/10.1080/00220670903383002

Prodjosantoso, A. K., Hertina, A. M., & Irwanto. (2019). The misconception diagnosis on ionic and covalent bonds concepts with three tier diagnostic test. *International Journal of Instruction, 12*(1), 1477–1488. https://doi.org/10.29333/iji.2019.12194a

Putranta, H., & Supahar. (2019). Development of physics-tier tests (PysTT) to measure students' conceptual understanding and creative thinking skills: A qualitative synthesis. *Journal for the Education of Gifted Young Scientists, 7*(3), 747–775. https://doi.org/10.17478/jegys.587203

Ramadianti, W., Priatna, N., & Kusnandi. (2019). Misconception analysis of junior high school student in interpreting fraction. *Journal for the Education of Gifted Young Scientists, 7*(4), 1159–1173. https://doi.org/10.17478/jegys.631567

Romine, W. L., Schaffer, D. L., & Barrow, L. (2015). Development and application of a novel rasch-based methodology for evaluating multi-tiered assessment instruments: validation and utilization of an undergraduate diagnostic test of the water cycle. *International Journal of Science Education, 37*(16), 2740–2768. https://doi.org/10.1080/09500693.2015.1105398

San Pedro, M, O, Z., Baker, R, S., & Heffernan, N. T. (2017). An integrated look at middle school engagement and learning in digital environments as precursors to college attendance. *Technology, Knowledge, and Learning, 22*(3), 243–270. https://doi.org/10.1007/s10758-017-9318-z

Sesli, E., & Kara, Y. (2012). Development and application of a two-tier multiple-choice diagnostic test for high school students' understanding of cell division and reproduction. *Journal of Biological Education, 46*(4), 214–225. https://doi.org/10.1080/00219266.2012.688849

Silverthorn, D. U. (2010). *Human Physiology: An Integrated Approa*ch (5th ed.). New York: Pearson.

Sloane, E. (2016). *Anatomi dan fisiologi: Untuk pemula.* Jakarta: EGC Penerbit Buku Kedokteran.

Smales, K., (2010). Learning and applying biosciences to clinical practice in nursing. *Nursing Standard, 24*(33), 35-39. http://dx.doi.org/10.7748/ns2010.04.24.33.35.c7716

Standing, S. (2015). *Gray's anatomy: The anatomical basis of clinical practice* (41st ed.). Amsterdam: Elsevier.

Tan Sisman, G., & Aksu, M. (2016). A Study on Sixth Grade Students' Misconceptions and Errors in Spatial Measurement: Length, Area, and Volume. *International Journal of Science and Mathematics Education, 14*(7), 1293–1319. https://doi.org/10.1007/s10763-015-9642-5

Taslidere, E. (2016). Development and use of a three-tier diagnostic test to assess high school students' misconceptions about the photoelectric effect. *Research in Science and Technological Education, 34*(2), 164–186. https://doi.org/10.1080/02635143.2015.1124409

Taufiq, L., Sriyati, S., & Priyandonko, D. (2017). Students' conceptual change on human reproduction concept using scientific approach. *International Journal of Science and Applied Science: Conference Series, 2*(1), 216–226. https://doi.org/10.20961/ijsascs.v2i1.16714

Teo, T. W., & Goh, W. P. J. (2019). Assessing lower track students' learning in science inference skills in Singapore. *Asia-Pacific Science Education, 5*(5), 1-19. https://doi.org/10.1186/s41029-019-0033-z

The Role of Scientific Knowledge in Research & Peer Review. (2016, January 20). Retrieved from https://study.com/academy/lesson/the-role-of-scientific-knowledge-in-research-peer-review.html.

Tongchai, A., Sharma, M. D., Johnston, I. D., Arayathanitkul, K., & Soankwan, C. (2009). Developing, evaluating and demonstrating the use of a conceptual survey in mechanical waves. *International Journal of Science Education, 31*(18), 2437–2457. https://doi.org/10.1080/09500690802389605

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10*(2), 159–169. https://doi.org/10.1080/0950069880100204

Treagust, D. F. (2006). *Diagnostic assessment in science as a means to improving teaching, learning and retention*. Paper presented at the UniServe Science Symposium: Assessment in science teaching and learning, Universe Science, Sydney, Australia.

Yang, D. C., & Sianturi, I. A. J. (2020). Sixth Grade Students' Performance, Misconception, and Confidence on a Three-Tier Number Sense Test. *International Journal of Science and Mathematics Education.* https://doi.org/10.1007/s10763-020-10051-3