Biological science misconceptions amongst teachers and primary students in Jordan: diagnosis and treatment

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Abstract

This study was conducted to identify and treat misconceptions in biological science content amongst teachers and primary stage students in Jordan during the scholastic year 2002/2003. The qualitative approach was used in collecting and analysing data. This study emerged from classroom observations during a pre-service science method course in the teacher education program offered at the University of Jordan in 2001/2002. Close observations indicated that teachers and primary students have many biological misconceptions that should be identified and treated properly. Results showed that students and teachers were accommodating many biological misconceptions in all topics covered by this study. Many conclusions were derived from these study findings, and based on these findings, it was recommended that pre-service teacher education programs should be reconstructed so that they account for diagnosing and treating biological misconceptions.
Keywords: biology, misconceptions, alternative concepts, preconceptions, naïve concepts, diagnosis, treatment, students, teachers.

1 Introduction

Misconceptions in biology among teachers and students vary in nature, consequence and tenacity. They cause failure in understanding biological phenomena and may be difficult to discover and address Newton [1]. Reasons for failure to understand biological concepts and phenomena are different. Difficulty in constructing an adequate, coherent mental representation of the phenomena, lack of relevant prior experience or failure in noticing the


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relationships between different concepts could be a possible factor for not understanding. This failure may exist in wide spectra of thought. Some students believe that acquired characteristics, such as rough hands, strong muscles and playing football skills can be inherited over several generations (Clough and Wood-Robinson [2]). Some kids avoid drinking water after eating fish because of the fear that bits rejoined in their stomachs (Ustinov [3]). But, are there any reasons for the origin of such misconceptions? Misconceptions may appear according to a variety of factors. Misinformation, selective attention, misinterpretation and other factors may stand behind the origin of misconceptions.

Students' understandings of the natural world are not always consistent with accepted scientific beliefs (Wandersee, Mintzes and Novak [4]). For teachers, it is important to know that the most important factor influencing learning is what students already know (Mintzes and Wandersee [5]). Biology and general science teachers should use different strategies to investigate students' concepts. Concept maps, discussion, small group works, specific activities, journal writing and pencil and paper tests have all been suggested to be suitable (Mintzes, Wandersee and Novak [6]; White and Gunstone [7]). Morrison and Lederman [8] analyzed science teachers' planning for evidence of any mention of the assessment of students, ideas. This analysis showed that teachers wrote down abbreviated plans for their lessons, but did not mention any interest in diagnosing students' preconceptions about science topics despite its vital influence in future learning.

The knowledge a student acquires is a result of their interaction with their environment and through special activities with parents, schoolmates, and others. These preconceptions do not always match or are not consistent with real scientific concepts. These discrepancies may confuse students and get in the way of the way they explain or interpret different scientific phenomena. This situation is known as misconceptions, alternative framework, naïve concepts, and primary concepts, or in other terminology used in the science education field. One can describe this misconception as two types, phenomenological and vocabulary (Esler and Esler [9]). Phenomenological concepts are associated with misinterpreting of phenomena; such as respiration is having oxygen through inhaling. Reasons behind this misconception may be as a result of limited experience or passed to students by other persons. The second type, which is the vocabulary one, results through limited experience. For instance students consider the word plant to refer to apple, orange, tomato and other food sources only, although plants are taught in different stages as all living thing that are not animals, fungi, protistans and monerans.

2 Previous studies about biological misconceptions

Many studies dealing with biological preconceptions and misconceptions have been implemented and this study refers to them in order to build the needed theoretical background. Arnaudin and Mintzes [10] implemented concept maps and structured/ clinical interviews to determine knowledge of human circulatory

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system among different age levels. Confrontation strategies showed an effect of changing preconceptions. Also, Arnaudin and Mintzes [11] observed many alternative conceptions about the human circulatory system among fifth and eighth grade students. Confrontation strategies were also efficient in diagnosing these alternative conceptions. Trowbridge and Mintzes [12] reported that some teachers think that the situation and distribution of alternative conceptions improves with student growth. Although, this was not the case in animal classification concepts, where students still showing alternative concepts throughout all school years, and constructivist view of learning should be implemented.

Gallegos and others [13] chose food chains as a field of studying student preconception. Preconceptions held by students on the construction of food chains were determined. Results showed that classification of herbivores and carnivores was based on children's preconceptions of size and ferocity. Gibson [14] noticed that not only teaching activities are sources of misconceptions, but also textbooks are sources of these misconceptions. An example of these misconceptions is what related to succession concept, which needs textbook revision and improvement. Evolution concept was found by Jensen and Finley [15] to be one of the important biological concept, which should take more consideration in teaching. As an application to treat these misconceptions, many instructional strategies were applied; paired problem- solving in conjunction with the historically rich biological curricula was found to be the best. Ferrari and Chi [16] found that mistaken categorization could cause misconceptions about natural selection, and pushed students to fail in understanding the ontological features of equilibrium processes. During the last year of the twentieth century, Mak, Yip and Chung [17] observed that junior high-level secondary science teachers showed many alternative concepts in biology related topics. Results showed that science teachers are not prepared to teach integrated science curriculum.

Internal body maps were investigated by Cuthbert [18]. The majority of 8-9 year old children thought that their body has no organs. While the majority of 7-11 year old children thought there are small and freely suspended organs. Kinchin [19] studied presetting materials related to photosynthesis through modified concept mapping activities to help students' awareness of their alternative preconceptions. Cartoons were used as a stimulus and encouraging factors for learning and the study found that this technique was efficient. Lewis and Wood-Robinson [20] found that students in United Kingdom seemed to have a poor understanding of the processes by which genetic information is transferred and a lack of basic knowledge about other related concepts such as chromosomes, cell division and inheritance. Also, Bianchi [21] stated that children's conceptual understanding of plants was a problem and it could be enhanced positively by hands-on activities. Alternative concepts about photosynthesis were diagnosed by Griffard and Wandersee [22] and they used the traditional paper-and-pencil tests. In using the second tier in asking students about reasons of their answers, the situation was different and some misconceptions were detected. In looking to inheritance, Marbach-Ad [23]

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identified many alternative concepts in the relationships between genetic concepts. These results gave recommended improving instructional strategies in teaching genetic concepts for different grades. Nazario, Burrowes and Rodriguez [24] made more investigations. They found that university students taking biology courses showed misconceptions during the pre- and post-tests in different biological topics. Ozay and Oztas [25] implemented a questionnaire to test students' concepts. Diagnosis reported conflicting ideas about photosynthesis, respiration and energy flow in plants among 9 grade (14-15 years old) Turkish students. Results showed that it was difficult to change students' prior concepts about these topics.

All those previous studies revised showed that there is a real problem in teachers and students' understanding of different biological concepts, which made the rationale base of doing this study.

3 How to deal with students' misconceptions

Dealing with students' misconceptions has many steps. Firstly, recognizing that misconceptions exist, and it is well known that concepts grow in students' cognitive structure by gaining more experience and knowledge. Secondly, the real conflicts arise between students' misconceptions and the right scientific concepts should be spotted. Thirdly, these concepts should be grouped into phenomenological and vocabulary ones to make dealing with them more doable and workable. Fourthly, treating these misconceptions by structuring teaching activities that will produce the needed conceptual change. Esler and Esler [9] reported that hands – on – experience is the best in treating phenomenological misconceptions, while defining words in the context of their use is an accepted and desirable mechanism for correcting vocabulary – based misconceptions.

It is well known that some misconceptions are easy to change, while other well - founded concepts in experience or which based on innate knowledge are difficult to change. There are many theories in dealing with misconceptions such as:

- The replacement theory, which treats the process as one of replacing existing mental structures with others. Enrichment and revision are recruited in this theory (Vosniadou [26]).
- Disconnected / Mini theories in which knowledge of the world supposed to be fragmented and composed of small knowledge structures. In this way difficulties in understanding the holistic view of the world arise (DiSessa [27]).
- Multiple representations theory, which mainly described by Caravito and Hallden [28]. This theory sees that we have a range of theories about the different phenomena in the world. Not all of these theories developed, but one or two. These different theories cause the conflict in students' understandings.

Beside these theories, there is more than one strategy adopted in treating different misconceptions. As there are several kinks of misconceptions, it is a mistake to think that one can treat all kinds in the same way. So, teachers should

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use a range of strategies to treat students' misconceptions. Many strategies were examined in this study such as, diagnosis, integration, differentiation and exchange strategy. Also activating students' prior learning, classroom demonstration, question – answer – explanation worksheets, and peer group discussion was used.

4 Method

This study was conducted to investigate diagnosing and treating of misconceptions in Biological Science content amongst teachers and primary students in Jordan during the scholastic year 2002/2003. This study followed the qualitative approach in collecting and analyzing data. Root of this current study emerged from classroom observations during a pre-service science method course in the teacher education program held in the University of Jordan in 2001/2002. Direct observations indicate that teachers and primary students have many Biological misconceptions, which need an urgent diagnosis and treatment. Aims of this study were dealing with answering the following questions:

- What strategy teachers used to diagnose Biological Science misconceptions?
- What are the misconceptions teachers and students have in primary Biological Science?
- How teachers and students deal and react with these misconceptions?
- What strategy teachers used to treat these misconceptions?
- To what extent teachers success in treating and modifying students misconceptions?

This study was designed depending on the qualitative approach and followed the following procedure in collecting and analyzing data. This process was carried as follows:

- Teachers who implement the Biological content (12 male and female) were asked to collect all data related to student dealing and manipulating of different Biological concepts in order to analyze this data and treat all misconceptions students have. Primary analysis of this data showed that students have many biological misconceptions (Chromosomes, genes and DNA are the same; Mother is the one who is responsible of deciding the sex of the baby; respiration and photosynthesis are the same; mixing between male and female flowers and difficulties in differentiating between vein and artery).

- An open discussion between researcher and teachers was made about what was done inside classrooms exactly in order to be sure that research procedure was carried in the right way.
- The later stage was implementing a program for modifying teachers' misconceptions.
- The last stage was observing and monitoring the effects of the remedial program of teachers' understandings of different Biological concepts, which related to the content covered in this study.

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5 Results

After collecting data a thorough analysis was carried out. Many important findings were found. First of all, misconceptions were emerged in Biological Science and not only Physical and Chemical Science as the thought was. Secondly, Biological misconceptions are spread amongst all Biological concepts and not only in the difficult contents like genes, photosynthesis and respiration. Thirdly, teachers and students, both have misconceptions. Fourthly, teaching and learning strategies affect students understanding of Biological concepts and they may cause building these misconceptions.

Units in which misconceptions appeared after analysis were:
Endocrine system, Circulatory system, Digestive system, Respiratory system, Execration system, Inheritance (Human Inherited diseases and Inheritance and Environment), Plants (Parts, Growth, Photosynthesis, Respiration and Nutrition) and Hearing Mechanism

Not all misconceptions appeared among students and teachers were reported in this study. In the different units mentioned above, types of misconceptions, diagnosis strategies, percentage of misconceptions among students and teachers and the treatment strategies were stated respectively and in one complete sentence to make it easy for the reader. In each time of misconception' treatment a disequilibrium situation was achieved by different techniques and strategies such as open discussion in order to help students move to the accepted scientific believes. The full results are as follows:

5.1 Endocrine and circulatory systems

Definition of the somatic gland: open discussion showed that 50% of students and 30% of teachers carry this misconception. To treat this misconception, discussion and knowledge replacement were applied. More gland secretion is a healthy symptom: Paper and pencil test, 100&40%, demonstrations of some human diseases caused by hormones' secretion irregularity.

Ventricles and auricles are the same: Drawings, 90&20%, demonstrations of drawings and film about differences between ventricles and auricles. Ventricles and auricles contract at the same time: Open discussion, 85&70%, demonstration of video film showing the human heart at work. Mixing between arteries and veins: Drawings and direct questions, 100&60%, using circulatory system charts and demonstration of lamb heart with arteries and veins.

5.2 Digestive and respiratory systems

Digestion happened inside living cells: Pencil and paper quiz, 90&50%, deep discussion about stages of digestion and stating differences between digestion in or outside cells. Also, concentrating on differences between digestion and cellular respiration. Water acts as a digestive factor or enzyme: Classroom discussion, 80&40%, applying hands-on-inquiry activities to prove that putting a piece of bread inside the water for long time doesn't change its chemical characteristics. Sugar detecting test was also used. Stomach is the only organ

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where digestion takes place: Direct questions, 90&35%, group discussion and knowledge replacement to show that the small intestine has a vital role in food digestion.

Inhaling, exhaling and internal gas exchange are used to indicate respiration: Open discussion about respiration mechanism, 75&25%, defining the respiration concept as the reaction of oxygen and food to produce energy. Exhaling gas has no oxygen: Open discussion about respiration, 100&65%, demonstration of one of the first aid activities (artificial breathing) and raising a question of the benefit of this aid. Respiration has nothing to be an activity of oxygen – food reaction to produce energy: Two-tier test about energy producing mechanism, 65&30%, classroom discussion and film demonstration about food journey inside human body.

5.3 Excretion system and inheritance

Sweating protects body from dryness: open discussion, 50&20%, concentration on the role of water in homeostasis and maintaining the body temperature. The relation between liver and kidney in producing urea is absent: group worksheets about producing urea in the body, 100&60%, discussing the stages of producing urea starting from having protein during feeding mechanism.

Concepts of chromosomes, genes, DNA, sex of the baby, sex-influenced characteristics, genotypes and phenotypes, sex-related genes, inherited diseases, and environment and inheritance relationship are all reflecting a real problem among students and teachers of a percentages about 90% or more among both students and teachers. It was easy to determine these misconceptions by classroom discussion. It took a comprehensive class activities and discussion to give the accepted scientific believes about the above concepts with both students and teachers.

5.4 Plants

Mixing between photosynthesis and respiration in plants as both students and teachers mentioned that both activities produce energy: diagnosis test was applied to explore the previous experience about these two concepts, 100% of students and 60% of teachers showing this misconception, using charts for both concepts and discussing each of them in depth, then the relation between the two was highlighted. Respiration happens in nighttimes only, while photosynthesis happens only during daytime: this mixing appeared accidentally during the classroom discussion, 80&60%, the problem appeared as a vocabulary one as the concepts were used in the wrong context. Teachers always said: photosynthesis happens in the light, while respiration happens at night. Mixing between pollination and fertilization: all students and teachers used both concepts as a word and it's meaning without differentiation. Discussing the mechanism of producing seeds was applied by using real flowers and charts with concentration in using each concept in the right place all the time.

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5.5 Hearing mechanism

Nerves have nothing to do with hearing mechanism and the human ears do all the job: Simple questions were enough to discover this misconception, 90&40%, deep discussion about the hearing mechanism and the role of the brain was highlighted.

Finally, the remedial program showed a moderate effect on students and teachers' understandings, which means that they still have problems in their explanations and dealings with concepts and more research effort is still needed. This means, more concentration and efforts should be given in teacher education programs to solidify and correct teachers' understandings of Biological Concepts before their real teaching practice.

6 Discussion and conclusions

Results of this study are strongly consistent with results of previous studies (Arnaudin and Mintzes [11], Bianchi [21], Marbach-Ad [23], Ozay and Oztas [25]), which indicate that the problem of having biological misconceptions among teachers and students is an international one. This should encourage researchers around the world to put this issue among their research priorities. This is because any future learning will be influenced positively or negatively of students' prior knowledge. Many conclusions were derived from these study findings. Diagnosis of misconceptions should take place for teachers and students side-by-side and only for students. All Science contents should be studied as a package (Biology, Physics, Geology and Chemistry) and not dealing with these contents lonely. This is because scientific concept is a result of these integrated contents and you cannot deal with blood concept without understanding other component of this concept rooted in Physics and chemistry as an example. Cross-sectional and longitudinal studies should be conducted for all school and college grades in order to indicate these misconceptions and deal with them in the right way and time. It is harmful to ignore any misconception; easily it will be resistant to change later on. Finally, teachers should receive dense teacher education program to be sure they got a good understanding of scientific concepts before the start teaching.

7 Recommendations and implications

The study findings will be helpful for teachers, students and all educators, especially curriculum designers, textbooks authors, trainers, parents, science teacher educators, administrators, teachers, student teachers and students. Finally, science teacher should give big effort for diagnosis and treating misconception as early as possible, otherwise the problem will be more difficult to be solved.

This study recommended applying different approaches in diagnosing and treating misconceptions among students and teachers. Pre-service teacher

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education programs should have a considerable interest, as it is the key for the future teacher to start his/her job.

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