Misconceptions and alternative concepts in biology textbooks: photosynthesis and respiration

Ideas falsas y conceptos alternativos en libros de texto de biología: fotosíntesis y respiración

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Abstract

Textbooks have a specific importance since they are used as the main instruction material. It is important to know that whether commonly used textbooks are adequate in terms of content and presentation. This study was performed to examine whether chapters on "photosynthesis" and "respiration" in the Biology-3 textbooks, that are used in secondary schools in Turkey are sufficient in terms of scientific content or not. We provide examples of the identified misconceptions along with their more acceptable alternatives. As a result, it was determined that biology-3 textbooks are insufficient in respect of scientific content. We recommend that biology-3 textbooks must be improved by correcting the scientific content.

Key words: *biology-3 textbooks, Scientific content, Photosynthesis, Respiration.*

Resumen

Los libros de texto tienen una importancia específica puesto que se utilizan como material principal de la instrucción. Es importante saber que si los libros de texto comúnmente usados son adecuados en términos de contenido y de presentación o, no. Este estudio fue realizado para examinar si los capítulos de la "fotosíntesis" y de la "respiración" en los libros de texto Biology-3 que utilizaron para la escuela secundaria en Turquía, es suficiente en términos de contenido científico o, no. Para esto, se proporcionan ejemplos de las ideas falsas identificadas junto con sus alternativas más aceptables. Consecuentemente, fue determinado que los libros de texto Biology-3 son escasos en lo que se refiere a contenido científico. Se recomendó mejorar los libros de texto Biology-3 corrigiendo el contenido científico.

Palabras clave: *biología, libros de texto, contenido científico, fotosíntesis, respiración.*

INTRODUCTION

Textbooks as instructional material guide teachers in topic selection and provide ways to teach those topics. Textbooks serve to provide the learner with the opportunity to consolidate his/her understanding independently of the teacher (Jones, 1997). Gottfried and Kyle (1992) have shown that the textbook plays a central role in the teaching of science and that the science curriculum is often designed around the structure of a textbook. The textbook for a biology course is the most consistently visible window on the biologist's profession. Like the adorned prow of a sailing vessel, this general textbook characterises the ship known as biology (BLYSTONE *et al.,* 1990). The textbook is the most significant tool an instructor has in teaching biology and is a principal means by which the public learns of the progress, thoughts, and aspirations of the discipline called Biology (BLYSTONE, 1987).

If a textbook is the primary resource for information and course design in biology class, it is important for the textbook to meet the needs of the teacher and student (KUECHLE, 1995). As a general rule, the best-selling books tend to succeed on some simple features: they tend to be better written, better organized, more accurate, and more pedagogical than their competitor (LEWIS, 1998).

Why haven't students learned the content of science? One way to answer that question is to ascertain the source of most of this information. From studies investigating instruction in the science classroom, research has found that textbooks have played a major role (Lloyd, 1990). Student misconceptions may be compounded by textbooks. In addition, the problem is accentuated when more than 90% of all science teachers use a textbook 95% of the time. Furthermore, textbooks may be a teacher's only source of information and may promote misconceptions among science teachers. Moreover, most of the effort in science education has been centered on writing science textbooks. Yet, gross misconceptions in textbooks have gone undetected (Odom, 1993). Students frequently demonstrate misconceptions of biological concepts that can be related to textbook design (BLYSTONE, 1987). High school biology textbooks fail to make big ideas comprehensible and meaningful to students (POZZER & ROTH, 2003). Science textbooks were found to be inadequate for determining and remedying misconceptions; in some subjects the textbooks included some parts that would cause misconceptions (KÜÇÜKÖZER *et al.*, 2008). STOREY (1991) decided to warn readers against believing what they read in science textbooks because of the large number of oversimplifications and outright errors they contain. CHO and KAHLE (1984) showed linear relationship between student achievement and textbook content.

This paper's focus is on selected misconceptions, alternative concepts and topics of confusion about photosynthesis and respiration in biology textbooks. Rather than a criticism of biology textbooks, this study is intended to share ideas with colleagues, teachers, students, publishers and textbook authors with the goal that we all become more effective in using biology textbooks to promote learning.

For the purpose of this study "misconception" is defined as an idea that is clearly in conflict with scientific conceptions and is therefore inadequate. We defined "alternative conception" as an idea which is neither clearly conflicting nor clearly compatible with scientific conceptions but which has its own value and is therefore not necessarily wrong (ABIMBOLA & BABA, 1996).

The main research question in this study was "are there any misconceptions and alternative concepts about photosynthesis and respiration in biology textbooks." Owing to this study, we expect to show that textbooks contain factual inaccuracies and mediocre explanations of concepts.

METHODOLOGY

We report here a study in Turkey in which we analysed biology textbooks. The following textbooks were searched for photosynthesis and respiration:

Title	Author(s)	Publisher	Date	Code
Biology-3	Sagdýç, Bulut, Korkmaz	MNE publication	2003	A
Biology-3	Berker, N	MEGA publication	2000	B

These textbooks coded as "A" and "B". They are a secondary (11th grade) biology textbook in Turkey. Only these textbooks were formally accepted in Turkey, so these two textbooks were used in this study.

For analysis of data, we followed the study by ABIMBOLA and BABA (1996). First, each text was read for meaning and overall organization of ideas. We examined the book page-by-page. We tabulated the identified misconceptions. Two senior lecturers in biology and education validated the identified conceptions together with the suggested alternatives. We asked them to evaluate the correctness or acceptability of our classification of the identified conceptions as either misconceptions or alternative conceptions based on the definitions given earlier.

RESULTS AND DISCUSSION

Textbooks were found to contain incorrect and alternative concepts. We present below alternative conceptions and misconceptions along with the suggested acceptable explanation.

-1-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A-B	Anaerobe respiration and fermentation	Anaerobe respiration is the same as fermentation. This is incorrect.	Fermentation is a catabolic process that makes a limited amount of ATP from glucose **without** an electron transport chain and produces a characteristic end -product, such as ethyl alcohol or lactic acid. Anaerobic respiration is a catabolic process in which a substance other than oxygen serves as the final electro n acceptor for the reactions. Fermentation is an anaerobic pathway that includes glycolysis, but it should not be called anaerobic respiration because no electrons flow through a membrane driving ATP synthesis (Storey, 1991).

-2-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A	NAD	NAD is an enzyme that carries H^+ and O_2. This is incorrect.	Because of the chemical structure of NAD, it can not transport O_2. It can carry electrons and protons (H^+).

-3-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A	Chlorophyll	Grana and granum were confused.	Plural of granum is grana. Thylakoids are stacked like poker chips, forming structures called grana (singular, granum).

-4-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A-B	Photosynthesis	Photosynthesis' phases are the light phase and the dark phase.	Photosynthesis takes place in two separate but dependent series of steps: the light dependent phase and carbon reduction phase. The d ark phase name is confusing as it implies that photosynthesis occurs in the dark in green plants. Carbohydrate production from CO_2 does not occur in the dark in green plants.

-5-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A	Photosynthesis	Water' quantity from factors that effects to photosynthesis is a hereditary factor. It is error.	Water' quantity is an environmental factor not hereditary factor that effects to photosynthesis.

-6-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
B	Photosynthesis	One of the necessary for photosynthesis is minerals. It is inaccurate.	Necessary for photosynthesis are H_2O and CO_2. Minerals supply the elements that are required by plants.

-7-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
B	Energy	Living organisms use energy' sources with their organ' systems. This is ambiguous	Cells trap and use energy. Living organisms use energy sources in their cellular pathways. Whatever manipulation and transformation about energy occurs at the cellular level (not organ level).

-8-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A-B	Photosynthesis	Cyclic and noncycl ic pathways happen in a sequence. Firstly cyclic and later noncyclic pathways occur. But, it is not in this way.	Whereas some living organisms use both pathway s, some use only one pathway. For example: ph otosynthetic bacteria use only the c yclic photophosp horylation pathway. Advanced plants use both pathways, but only the cyclic photophosphorylation pathway or noncyclic photophosphorylation pathway in some cases.

-9-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A	Aerobe respiration	All of examples that are given for aerobic respiration are about humans breathing The textbook regarded breathing as synonymous with respiration. This is a misconception.	Breathing is a term conventionally used to describe the visible, mech anical intake (inhalation) and expulsion of air (exhalation) involved in aerobic respiration with the aid of the vertebrates' lungs or tracheae of some insects. For aerobic respiration, most plants also exchange gases by taking in and sending out air by simple diffusion through the lenticels in their stems and the stomata in their leaves (Soyibo, 1995).

-10-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A-B	Photosynthesis	Photosynthesis' equation: $6H_2O+6CO_2 \longrightarrow C_6H_{12}O_6$ This equation is net consumption of water. This equation causes the misconception that students may think the oxygen given off by plants is derived from CO_2 and not water. This is untrue as the oxygen given off by plants is derived from water.	$12H_2O+6CO_2 \longrightarrow 6O_2+ C_6H_{12}O_6 + 6H_2O$ or $2H_2O+CO_2 \longrightarrow O_2 + (CH_2O)+H_2O$ H_2O appears on both sides of the equation because 12 molecules are consumed and 6 molecules are newly formed during photosynthesis.

-11-			
Textbook	**Subtopic**	**Misconceptions/ Alternative Concepts**	**Acceptable Explanation**
A-B	Aerobe respiration	Total net energy yield of aerobic respiration is 38 molecules of ATP.	Two electrons of NADH captured in glycolysis are passed either to NAD^+ or to FAD from within the cytoplasm to mitochondrion/ia If the electrons are passed to FAD, only 2 ATP can result from each cytosolic $NADH_2$. If the electrons are passed to NAD, only 3 ATP can result from each cytosolic $NADH_2$. Hence, total net energy yield of aerobe respiration is 38 ATP or 36 ATP.

Textbooks support the curriculum for science courses. The textbook, therefore, becomes one of the major sources of information and, perhaps, misconceptions (Cho *et al*., 1985). Blystone (1990) stated that there are common failings in biology textbooks. Only in the late 1980s and 1990s have researchers focused attention on alternative conceptions of students at higher cognitive levels and correspondingly investigated more biochemical concepts, such as cellular respiration, photosynthesis, cell division and transcription and translation (Canal, 1999; Fisher, 1985).

Respiration is one of the biology topics that many students regard as difficult to understand (Haslam & Treagust, 1987). This is partly due to some misleading terms usually associated with the topic, and the misconceptions and misunderstandings perpetuated about it by teachers and textbooks of biology (Barrass, 1984). Soyibo (1995) analysed science textbooks for presentations on respiration. He identified defects in the texts. Storey (1991) identified misconceptions about respiration and fermentation and Storey (1989) identified misconceptions about photosynthesis in biology textbooks. Seymour and Longden (1991) studied about connection and confusion of respiration- breathing. In this study, some identified defect are similar with Soyibo (1995), Seymour and Longden (1991) and Storey (1989, 1991).

On the basis of the findings of this paper we suggest the following to science teachers, students, publishers, textbook authors and the Ministry of National Education.

CONCLUSIONS AND IMPLICATIONS

Attention must be given to the cognitive design of biology textbooks as it may relate to a potential for misconceptions. Every biology teacher knows, or strongly suspects, that the textbooks they must use in their classrooms need to be reviewed and rewritten to promote better scientific literacy (Nelson, 2001). Rutzitis (2003) suggests that one of the main concerns about teaching science at secondary school and university is the design of a new kind of textbook and tasks for independent work for students so that they develop their. Biology teachers should carefully screen the textbooks that will be used as reference materials during biology. Teachers, publishers, scientists and text authors should be in communication. Teacher education institutions should encourage trainee teachers to analyse textbooks to determine their accuracy. Biology-3 textbooks can be improved by correcting scientific content.

In subsequent articles I will identify other misconceptions, inadequacies and alternative concepts that seem biology textbooks.

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Our group is focused on the study of environmental factors (i.e. air pollution, sun exposure, pesticides, water pollution, diet, smoking etc) that could cause serious health problems particularly to children, who constitute a very sensitive population group. Furthermore, we are interested in the use of Information and Communication Technologies (ICT) in relation to health issues (information, educational interventions, etc). Classical and Molecular Epidemiological studies are carried out using suitable methodological tools such as questionnaires and Molecular Biology methods. Our goal is to inform and educate these immediately affected populations in order for them to take suitable preventive measures which will minimize the dangers.

PERSONNEL-RESEARCH PROJECTS

1. Stylianos M. Piperakis, B.Sc., Ph.D., Head of Unit,
   "Effects of Environmental Factors on Human Health".
2. Maria Papanikolaou, B.Sc. Postgraduate Student,
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3. Argyro Aggelosopoulou, B.Sc., Postgraduate Student,
   "Bio-psychological Factors of Bronchial Asthma in Childhood".
4. Maria Koroni, B.Sc., M.Sc., Postgraduate Student,
   "Biological, Psychological and Social Aspects of Children's Obesity".
5. Nantia Kontogianni, B.Sc., Research Associate,
   "Sensitivity of Children's Genetic Material (DNA) Exposed to External Factors".
6. Georgia Karanastasi, B.Sc., Research Associate,
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