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LIVING CREATURES BREATHE AND RESPIRE

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Abstract: *The goal of our research is to establish the quality of knowledge of Slovenian students at 14 years of age when they leave school, regarding the process of breathing/respiration and its significance for living beings. The survey utilized a test with five open-ended questions. We included students of two levels of education; one where they had not yet learned about breathing/respiration and cellular respiration in school (13 years old), and the other where they have already discussed both processes (15 years old). Experience shows that students often fail to distinguish between these two processes, or only know about breathing/respiration in the sense of exchange of gases. The results showed that both groups of students considered breathing/respiration primarily as an exchange of gases, and that breathing/respiration is important because it enables survival. Only 5.3 % of the students wrote that breathing/respiration produces energy. It was also shown that the 13 year olds have slightly simpler concepts of certain aspects of breathing/respiration than the 15 year olds. The most important discovery was that, compared with the 13 year olds, the knowledge of the 15 year olds didn't show any visible effect of teaching or progress in understanding of the importance of breathing/respiration for living beings. We assume that these results are a reflection of inadequate methods of work in the classroom.*

Key words: *breathing, respiration, cellular respiration, primary school*

Introduction

Life processes are a complex area of biology and, as we know from experience, can be very problematic for students. Teachers are faced with the problem of how to present the content in the most understandable way, while at the same time providing students with what they need to take from classes. Students need this knowledge to be able to understand their health now and in the future, as well as to have a solid foundation for any further education. Understanding the fundamentals of life processes is an integral part of scientific literacy in the modern world.

The term breathing means ventilation of the lungs, a process which makes gas exchange (intake of oxygen into the body and release of carbon dioxide from the body into the environment) more efficient. The expansion and contraction of the chest in

humans is the externally visible indicator of the gas exchange process. Living organisms need to obtain oxygen in order to carry out respiration. Respiration is a chemical reaction occurring in all cells of the body to make energy (Millican and Barker, 1997). In foreign scientific literature the term respiration is also called 'cellular respiration' (Mader, 2009). In Slovenian the terms 'breathing' or 'lung breathing' are used for the process of gas exchange between the organism and the environment, and 'cellular breathing' for the process in the cells where energy is produced. In practice we often speak only about breathing, even when we're talking about the cellular level. This makes the already complex subject even more confusing. Given the partial semantic differences between Slovenian and English terminology we decided to use both terms, breathing and respiration, simultaneously throughout the paper.

In our study we wished to determine the level of knowledge of breathing/respiration of Slovenian students at 14, when they leave general-education school. Based on the information we had from previous research, we expected students to know exactly what oxygen is and which organisms breathe. We expected medium-level knowledge about the question of what breathing/respiration is, the lowest-level knowledge about the importance of oxygen in nature, and the significance of breathing/respiration in nature.

Materials and Methods

The survey included students of two levels of education; one where students had not yet learned about breathing/respiration and cellular respiration at school (58 students; 13 years old), and the other where students have already discussed both processes (56 students; 15 years old). As part of their regular classes the students completed a test with the following 5 open-ended questions:

1. What is oxygen?
2. What is the significance of oxygen in nature?
3. Which organisms breathe/respire?
4. What is breathing/respiration?
5. What is the significance of breathing/respiration in nature?

All students' answers to each question were evaluated and categorized. Some of the responses that did not fit in any of the categories were not used in the subsequent detailed analysis and are not included in the percentages of individual responses. We believe that the credibility of this research was not adversely affected, since our intention was to find general perceptions of the students which our method successfully achieved.

The students responded in more or less complex sentences, so their answers could often be classified in more than one category. For example, to the second question (What is the significance of oxygen in nature?) a student replied "humans and animals need oxygen to survive." The response was classified into two categories: (1) why do we need oxygen and (2) who needs oxygen. Calculated response percentages shown in the tables therefore don't equal 100 percent, but may exceed 100 %.The data was analyzed with the SPSS 17.0 statistical program. The statistical significance of the differences between the responses of the two age groups was assessed by utilizing the Mann-Whitney U test.

Results and Discussion

Altogether we had 114 students who took part in our survey, though not all of them answered all five of the questions (Table 1). We assumed that a student who didn't answer a question wasn't familiar with the topic enough to even try to answer. A low percentage of responses to a question would therefore mean that the topic was unfamiliar to the students. The first four questions (What is oxygen?, What is the significance of oxygen in nature?, Which organisms respire?, What is breathing/respiration?) were answered by most of them (72.8-91.2 %), from which we concluded that they found this content familiar and that they had confidence in their knowledge (which doesn't mean their answers were correct, though). In contrast, the last question was answered by only 50 % of students, from which we concluded that they didn't quite understand the significance of breathing/respiration in nature. This figure is alarming, since breathing/respiration is an important concept that students need to know when they finish general-educational primary school. Many of them will never have the opportunity to acquire this knowledge in their future education.

Table 1: Frequency of students' answers to five questions (N = 114)

	Students' responses	
Questions	**Frequency**	**%**
What is oxygen?	104	91.2
What is the significance of oxygen in nature?	94	82.5
Which organisms breathe/respire?	97	85.1
What is breathing/respiration?	83	72.8
What is the significance of breathing/respiration in nature?	57	50.0

Percentages of the responses to individual questions provided just the general picture of the students' knowledge; actual knowledge was established with a detailed content analysis verifying the accuracy of the answers.

1. WHAT IS OXYGEN?

Students gave a number of very different answers to this question (Table 2). Most students of both age groups (89.4 %) wrote one or more chemical definitions or properties of oxygen, such as:

"Oxygen is a gas."
"Oxygen is a part of air."
"Oxygen has no colour or taste."

In addition, students wrote other, biological explanations, but these were much less common than the chemical explanation (1.0-42.3 %). Biological explanations were classified into three categories, namely: why do we need oxygen; which organisms need oxygen; and production of oxygen. Biological explanations showed statistically significant differences between the younger and the older students (Mann-Whitney U test, $p < 0.05$). The typical biological response in the younger group was that the oxygen is needed for breathing/respiration, while the typical response in the older group was that

the oxygen is necessary for survival. We see that the majority of the younger students think of the process of breathing/respiration as we see it, i.e. as expansion and contraction of the chest. The knowledge of the older students was at a slightly higher level, because they gave more thought to the significance of oxygen.

When describing who needs oxygen, students of both age groups most frequently mentioned humans (42.3 %). However, this response is statistically significantly more frequent in the younger group than in the older (Mann-Whitney U test, $p < 0.05$). We believe that this is due to the fact that in the thinking of 13 year old students a human is still at the core of living beings. In contrast, the 15 year olds are increasingly aware that a man is only one of the living beings and therefore gave statistically significantly more answers that oxygen is needed by organisms (Mann-Whitney U test, $p < 0.05$). Some students answered that oxygen is needed by animals or plants (4.8 %, 1.0 %). In their explanation of what oxygen was some students (5.8 %), mostly older (Mann-Whitney U test, $p < 0.05$), found it necessary to indicate that oxygen is produced by plants or in the process of photosynthesis.

Table 2: Response percentages and statistically significant differences between the answers of 13 year old and 15 year old students to the question of "What is oxygen?"

Categories	**Response percentages (%)**	**Statistically significant differences**	**More frequently answered by**
1. Chemical definition	89.4	---	---
2. Why do we need oxygen			
Breathing	39.4	0.000	13 year olds
1. Survival	25.0	0.002	15 year olds
ɔ. Who needs oxygen			
Humans	42.3	0.011	13 year olds
Organisms	10.6	0.005	15 year olds
Animals	4.8	---	---
Plants	1.0	---	---
4. Production of oxygen	5.8	0.001	15 year olds

2. WHAT IS THE SIGNIFICANCE OF OXYGEN IN NATURE?

Interestingly, the responses to this question (Table 3) were very similar to the answers to the first question where the students were asked what oxygen is. Most students (85.5 %) stated that oxygen is needed for breathing/respiration, while much less common response was that it is necessary for survival (30.9 %). Some students also indicated who requires oxygen (11.7-20.2 %) and where it is produced (11.7 %). There were no differences between the responses of the younger and the older students (Mann-Whitney U test, all $p > 0.05$). We see that the students knew that living things need oxygen, but their knowledge did not reach the level which would enable them to also understand the deeper reason for the need for oxygen.

Table 3: Response percentages and statistically significant differences between the answers of 13 year old and 15 year old students to the question of "What is the significance of oxygen in nature?"

Categories	Response percentages (%)	Statistically significant differences
5. Why do we need oxygen		
Breathing	85.5	---
Survival	30.9	---
6. Who needs oxygen		
Humans	20.2	---
Animals	16.0	---
Organisms	16.0	---
Plants	11.7	---
7. Production of oxygen	11.7	---

3. WHICH ORGANISMS BREATHE/RESPIRE?

In response to the question "which organisms breathe/respire" we expected students to list individual groups of organisms, but most responded with a general answer that "living things" breathe/respire (75.3 %, Table 4). The answers listing groups of organisms mentioned animals and humans with the same frequency (22.7 %) while plants were mentioned less frequently (17.5 %). Only a few students indicated that also bacteria and fungi breathe/respire (3.1 %). There were no differences between the responses of the younger and the older students (Mann-Whitney U test, all $p > 0.05$).

Table 4: Response percentages and statistically significant differences between the answers of 13 year old and 15 year old students to the question of "Which organisms breathe?"

Categories	Response percentages (%)	Statistically significant differences
1. Living beings	75.3	---
2. Animals	22.7	---
3. Humans	22.7	---
4. Plants	17.5	---
5. Bacteria	3.1	---
6. Fungi	3.1	---

4. WHAT IS BREATHING/RESPIRATION?

This question was answered by 72.8 % of students, which is much less than the first three questions with 82.5-91.2 % (Table 1) of answers. We therefore conclude that some students didn't have a well-defined notion of what breathing/respiration is. Most

often the students wrote that breathing/respiration means inhalation of air into the body or lungs, and exhalation of the air from the body or lungs (36.1 %; Table 5). Younger students gave this response statistically significantly more often than the older students (Mann-Whitney U test, $p < 0.05$). Almost as frequent was a response that breathing/respiration is an exchange of gases between the body and the environment (33.7 %); this answer was statistically significantly more frequent in the older group (Mann-Whitney U test, $p < 0.05$). We concluded that the majority of younger students formed a very simple understanding of breathing/respiration, including only the process of breathing/respiration as we see it, namely the expansion and contraction of the chest. Such understanding was still held by some 15 year olds, but the majority had a little more advanced understanding that included the process of gas exchange in breathing/respiration.

The concept of breathing/respiration as a cellular process in which energy is generated using oxygen (cellular respiration) was clear only to a very small proportion of students (13.2 %) and to the same extent in both age groups (Mann-Whitney U test, $p > 0.05$).

Table 5: Response percentages and statistically significant differences between the answers of 13 year old and 15 year old students to the question of "What is breathing?"

Categories	**Response percentages (%)**	**Statistically significant differences**	**More frequent**
1. Breathing in and out	36.1	0,001-0,02	13 year olds
2. Exchange of gases	33.7	0,038	15 year olds
3. Cellular process	13.2	---	---

5 WHAT IS THE SIGNIFICANCE OF BREATHING/RESPIRATION IN NATURE?

This question was answered by 50.0 % of the students, which is significantly less than the first four questions with 72.5-91.2 % of answers (Table 1). We therefore concluded that a large proportion of students did not have a well-formed understanding of the concept. A quarter of students (24.6 %) stated that breathing/respiration is important, but didn't give any reason for it. The most common response (65.0 %) which also contained the reason was that breathing/respiration is a condition for life ("Without breathing/respiration there is no life." Table 6). All those answers, similarly to the answers to the question of what breathing/respiration is (Question 4), showed poor understanding of the concept of breathing/respiration, as they remained at a very simple level of explanation. The appropriate response – that it is a process which supplies cells with energy was given by only 5.3 % of the students.

It is surprising that the answers of 15 year olds were no more correct or complete than 13 year olds' (Mann-Whitney U test, all $p > 0.05$). This figure shows that the preconceptions held by students before addressing cellular breathing/respiration continue into later years and students don't correct or deepen their knowledge. Perhaps these students demonstrated knowledge of cellular breathing/respiration in biology classes that earned them their best grades, but, as shown by our results, this knowledge remains isolated, not integrated into the conceptual network, and not comprehended.

Table 6: Response percentages and statistically significant differences between the answers of 13 year old and 15 year old students to the question of "What is the significance of breathing in nature?"

Categories	Response percentages (%)	Statistically significant differences
1. Enables survival	65.0	---
2. Breathing is important	24.6	---
3. Generates energy	5.3	---

Our study showed that students' lack knowledge about the process of breathing/respiration, which is not surprising considering that this topic is also problematic for pre-service teachers, as was found in a recent survey (Bajd, Praprotnik, Matyášek, 2010). This survey involved first year students of Faculty of Education in the Czech Republic and Slovenia, who would eventually teach all subjects at the primary level, and are therefore not specialized in biology. It is important that these teachers also master the basic biological concepts. They will be identifying naive conceptions and pre- or misconceptions in the youngest students and correct them. We know that such concepts are deeply rooted and difficult to reject, even if one is faced with convincing evidence that their thinking is false (Elrod, 2007). Misconceptions are a major barrier to learning, so we need to recognize them if we are to be effective in teaching. Real misconceptions are probably less common than naive conceptions. The answer that breathing/respiration is important for survival is not really wrong, just very simple. A student that gives this answer has a certain extent of knowledge about breathing/respiration, but it's not advanced enough to create a more complex response. On the other hand, a student who answers that breathing/respiration is important because it supplies cells with energy shows a higher level of knowledge.

Examination at the national level also showed that Slovenian students are less familiar with life processes such as cellular breathing/respiration (Jagodnik *et al*., 2009). The results of the international PISA study indicated that Slovenian schools emphasize the development of knowledge of the biological content, but lacks development of other skills, such as the ability to scientifically explain phenomena and the ability to use data (Strgar, 2008, Štraus, Repež, and Štigl, 2007). Even the international TIMSS study found that the knowledge of the Slovene students focuses too much on facts, and that they achieve higher levels of knowledge less often than their peers in comparable countries around the world (Japelj Pavešić *et al*., 2005).

The knowledge of breathing/respiration is therefore not all-rounded. A better quality of knowledge could be achieved by linking content within biology, which means that students must learn to generalize and integrate it in order to advance from the reproduction level to the level of understanding and integration (Skribe-Dimec, 2000, Šorgo and Hajdinjak, 2006). Teachers can help students to better connect the knowledge they already possess. Teachers must accept the fact that preexisting concepts exist and try to use them in a positive way, and take advantage of the students' prior knowledge as a base, but a base that needs clarifying. A teacher should be an organizer and leader, and

no longer just a channel for knowledge, and would need to dedicate more lesson time to methods such as consolidation, research, and discussing (Jedličkova and Tymrakova 2010, Šorgo, 2008). Materials that would encourage students towards active work methods also need to be prepared (Tomažič, 2008).

Conclusions

1. What is oxygen?

We found that Slovenian students knew the correct simple definition of oxygen (89.4 % correct answers), for example that the oxygen is a gas or that is odorless and tasteless.

2. What is the significance of oxygen in nature?

We found that most students think that oxygen is important for breathing/respiration (85.5 % of responses). 30.9 % of students felt that oxygen is important because we need it to survive. None of these answers is wrong, but both are very simple.

3. Which organisms breathe/respire?

We found that most students (75.3 %) knew that living beings or living organisms breathe/respire. Unfortunately, only a small proportion of students also indicated specific groups of organisms, which was what we wanted to know. A common misconception is that animals breathe/respire, but plants photosynthesize instead. This question should therefore be rephrased and given to students again.

4. What is breathing/respiration?

We found that most students (69.8 %) think breathing/respiration is inhalation and exhalation of air, or gas exchange. None of these answers is wrong, but both are very simple. Only 13.2 % of students gave a more advanced response that breathing/respiration is a cellular process.

5. What is the significance of breathing/respiration in nature?

We found that most students (65.0 %) responded that breathing/respiration is important because it enables survival. The answer is not wrong, but it's very simple. A more complex answer − that the process of respiration produces energy – was given by only 5.3 % of students.

It was also shown that 13 year old students had marginally simpler concepts of some aspects of breathing/respiration than 15 year olds. The most important finding is that the knowledge of students didn't show any visible effect of teaching in terms of understanding of the deeper meaning of breathing/respiration for living creatures. We concluded this from the fact that the answers of the older group that already discussed cellular breathing/respiration in class were just as incomplete as the answers of students who were two years younger that haven't yet learned about it. If we want future generations to understand breathing/respiration more fully, teachers must not only provide knowledge but should help students with integration and generalization of that knowledge.

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ŽIVÉ BYTOSTI DÝCHAJÍ

Abstrakt: V našem výzkumu jsme chtěli zjistit, jakou kvalitu znalostí o procesu dýchání a jeho významu mají slovinští žáci ve 14letech, kdy ukončí povinnou školní docházku. Ve výzkumu jsme použili test znalostí s 5 otevřenými otázkami. Do výzkumu jsme zahrnuli žáky dvou stupňů vzdělání – v jednom byli žáci, kteří se ještě neučili o dýchání a buněčném dýchání (13letí), ve druhé pak žáci, kteří se ve výuce již seznámili s oběma procesy (15letí). Praxe ukazuje, že žáci často nerozlišují mezi oběma procesy, anebo znají dýchání jenom jako výměnu plynů. Výsledky nám ukázaly, že žáci obou skupin chápou dýchání především jako výměnu plynů a že vědí, že je dýchání důležité, protože nám umožňuje přežití. Pouze 5,3 % žáků uvedlo, že při dýchání vzniká energie. Ukázalo se také, že měli 13letí žáci poněkud jednodušší představy o některých hlediscích dýchání než 15letí. Nejdůležitějším zjištění bylo, že jsme nezjistili ve znalostech 15letých, viditelný vliv výuky, respektive pokrok v porozumění významu dýchání pro organismy v porovnání s 13letými. Domníváme se, že získané nepříliš uspokojivé poznatky jsou výsledkem nevhodných vyučovacích metod.

Klíčová slova: dýchání, buněčné dýchání, výuka