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Secondary School Students' Misconceptions about Photosynthesis and Plant Respiration: Preliminary Results

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The study investigated the common misconceptions of lower secondary school students regarding the concepts of photosynthesis and plant respiration. These are abstract concepts which are difficult to comprehend for adults let alone for lower secondary school students. Research of the students misconceptions are conducted worldwide. The researches show that many students do not even understand the fundamental concept that photosynthesis and plant respiration are related, mutually connected physiological functions. Many mistaked photosynthesis for plant respiration and that respiration took place only in leaves where are special organs such as pores. They also believed that the plant produced oxygen over the entire day and that the most important source of food for plants is water with dissolved mineral substances. The research showed that Czech students have many misconceptions about photosynthesis and plant respiration. In the study, we finaly go on to propose teachers that teachers could eliminate misconceptions by graphic explanation of these concepts, correct chemical clarification of photosynthesis and respiration, and connecting integration about this processes. The study sample size consisted of 108 lower secondary school students (age 11 – 16 years) in the Czech Republic. The questions were designed in two parts: the first part was focused on the students knowledge, and the second part on the explanation of the answer. The data was analyzed in several ways first by the students' knowledge (correct/incorrect answers), then by their misconceptions (frequency of occurrence of misconceptions).

Keywords: photosynthesis, plant respiration, misconceptions, secondary school students, two-tier test

INTRODUCTION

The topic of this study is the examination of students' misconception about plant physiology (in particular photosynthesis and plant respiration). The literature presents a somewhat blurry picture of what exactly "misconceptions" are, for example: alternative student's conceptions, children's conceptions, misunderstanding, naïve theories, wrong ideas or alternative framework. Chi and Roscoe (2002, p.3) in their work presented misconceptions as "ontological miscategorizations of concepts", which are persist strongly and robust. Either Wandersee (1986) says: "The term 'misconception' is often used to describe an unaccepted (though not necessarily 'incorrect') interpretation of a concept by the learner." However, for the purposes of this study, "misconceptions" are understood as a misunderstanding of a scientific concept.

It is well known that students' misconceptions in science are pervasively stable and, as a general rule, are

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State of the literature

- The study extends and replicates current knowledge about misconceptions in the field of plant physiology.
- The research study focused on the investigation of misconceptions of lower secondary school students regarding photosynthesis and plant respiration was not performed in Czech Republic. A similar study was also performed with university pedagogy students.
- Contribution of this study is useful because such studies in the Czech Republic are missing, and the study shows that misconceptions still persists despite efforts of teachers.

Contribution of this paper to the literature

- The study illustrates the variety and quantity of misconceptions by secondary school students about the concepts of photosynthesis and plant respiration.
- Different forms of teaching are evident across Czech Republic and many teachers do not understand misconceptions like this might exist Consequently, many teachers do not work with students to correct these flaws, and as a result, people may hold these misconceptions for there whole life.
- To develop science literacy we must work with the students to understand that as young students learn they develop their own theories to fill knowledge gaps, and it is not until given a different theory will they adjust their thinking.

resistant to change, at least through traditional instruction (Fisher, 1985). As a result, misconceptions about natural phenomena are often held by people their whole life. To overcome misconceptions, students must become aware of the scientific concepts, the evidence that take on the validity of their misconceptions and the scientific concepts, and they must be able to generate the logical relationships between the evidence and alternative conceptions (Lawson, Thompson 1988).

Sneider and Ohadi (1998, p. 66) in their work wrote that "[m]any researchers object to the term 'misconception' because, from the student's point-of-view, the ideas expressed are logical. 'Preconceptions', 'naïve theories', and 'alternative frameworks' have been proposed as better terms for students' personal views that are at odds with modern scientific theories." Misconceptions most often arise by misapprehension or bad understanding of curriculum when students do not create a symbiosis with curriculum (one part of curriculum is acquired by students but second part is interfaced with earlier bad preconception). Part of the student's knowledge remains unchanged and further disrupts learning.

Theoretical background

There exist many researches, which address misconceptions in biology education. The researches often deal with concrete topics, such as: individual groups of animals, structure of the human body, description of the various organ systems, description of certain botany taxonomic groups, and misconceptions in abstract fields of biology education, such as photosynthesis and plants respiration, genetics, viruses etc.

Researches of students' misconceptions about photosynthesis and plant respiration are widely studied topics worldwide. In 1987, Haslam and Treagust published the research, where the misconceptions held by 13–17 years old Australian students were investigated. The purpose of their study was to describe the development of a two-tier instrument to reliably and validly diagnose secondary students' understanding of photosynthesis and respiration in plants. The results indicated that a high percentage of secondary school students do not comprehend the nature and function of plant respiration and have little understanding of the relationship between photosynthesis and respiration in plants. Using a questionaire with seven open-ended questions, Özay and Öztas (2003) obatined similar results with Turkish 14-15 years old students. The authors suggest that misconceptions are influenced by the school curriculum. Students have, as general rule, individual knowledge about plants, photosythesis, respiration, chemical processes in plant but they cannot asociate this knowledge into one coherent complex. With a similar questionare as Özay and Öztas, Marmaroti and Galanopoulou (2006) conducted their research with 13 year old Greek students. The authors concluded that photosynthesis is very difficult biology topic because which is characterized by the large number of views on the topic (i.e. ecological, physiological, biochemical, energetical etc.). The results showed students have conflicting, and offen incorrect, ideas about photoynthesis and respiration, even after teaching. Students understand photosynthesis as an integral constituent of processes which are taking place in the green parts of plants (primarily in leaves). They know when and where photosynthesis is in motion, but they do not understand the function and presence of chlorophyll (even though they know that chlorophyll is a necessary constituent of photosynthesis). Students do not distinguish between photosynthesis and plant respiration. Twenty percent of the students have the misconception that plants respires only if photosynthesis is not occuring, and another 20 % of the students believe that photosynthesis is one of

Table 1. The basic demographic variables of the sample size

Total number of respondents	Boys	Girls	Grade				Favorite subject	
			6.	7.	8.	9.	Science	Another than science
108	53	55	29	30	23	26	10	98

possibilities how plants respire. Anderson, Sheldon and Dubay (1990) point out in their study that students of all ages show markedly similar misconceptions about photosynthesis. Their study showed that even if students have no knowledge connected to photosynthetis, they are aware of some processes happening in plants and other botanical material, which, as the results of the study suggest, provides the basis for the creation of misconceptions.

As outlined in the aforementioned studies, students have many common misconceptions regarding plant physiology, especially from photosynthesis and plant respiration. They do not understand processes which are taking place in plants. In the Czech Republic this problem is not examined and data from similar research are missing. Understanding of misconceptions can help teachers in their preparation for teaching. If teachers know what students do not understand (generally what is incorrect in the students understanding of science concepts) teachers can work better with the students to eliminate misconceptions. One of methods which teachers can use to organize valid concepts or eliminate misconceptions is to introduce a conceptual change text. A study by Yenilmez and Tekkaya (2006) investigated "the effectiveness of combining conceptual change text and discussion web strategies on students' understanding of photosynthesis and respiration in plants." The results showed a significant increase in the understanding of photosynthesis and respiration in plants when using conceptual change texts.

Further, misconceptions can be swayed by attitudes toward science. This topic was discussed by Usak et al. (2009). The Usak study showed that positive attitudes to science are associated with better learning outcomes in spite of the results indicated only weak, although statistically significant, association between attitudes and achievement. Teachers could promote positive attitudes toward science by highlighting new findings in science and encouraging students to do their own research – such motivated students will not settle with information from school and teachers, they will look for new information on the internet, science TV programes, etc.

MATERIALS AND METHODS

Purpose of the study

The main aim of study was to examine the level of misconceptions by lower secondary school students on the topics of plant physiology (primarily misconceptions about photosynthesis and plant respiration). The secondary aims are the influence of gender, year of study, favorite subject and attitudes toward biology verses the degree of misconceptions.

We achieved this by asking the following research questions:

Q1: Is there any difference between boys and girls in the level of misconceptions about photosynthesis and plant respiration?

Q2. How do misconceptions about photosynthesis and plant respiration change with the student's year of study?

Q3: Is there any difference in the misconceptions about photosynthesis and plant respiration with the respect to favorite subject?

Q4: Can attitudes toward biology change level of knowledge and misconceptions about photosynthesis and plant respiration?

Participants

The sample size included lower secondary school students from grade 6 to 9 (see table 1). Girls accounted for 59.4 % of the sample size. The age of students was from 11 to 16. Respondents were from six intact classes of the same lower secondary school located in an urban area.

Respondents were divided by their favorite subject into two groups: respondents who had one science subject marked as favorite (n = 10), respondents whose favorite subject is one another than science (n = 98). Listed science subjects were integrated biology, physics, chemistry and geography.

Research tool

The research tool is divided into four parts. The first part includes introduction information about the research tool and how to complete it. The second part contains demographic variables (gender, grade and favorite subject). The third part is the test and the fourth part is the questionnaire regarding attitudes toward biology. The test part is graded as two-tier test in which the answer is collected in two steps: in the first step, students choose the correct answer of a multiple-choice questions (the knowledge part of test) and in the second step, students opt for the explanation of the answer. The test part consists of 19 questions with 2–4 answers and with 2–4 explanations. The fourth part of research tool was made up of a questionnaire with 17 items regarding to attitudes towards biology. The items were 5-point Likert type items (from strongly disagree to strongly agree).

The research tool was developed based on the tools developed by authors Haslam and Treagust (1987), but modified for the Czech enviroment and different aims. The knowlegde questions were graded taking into account the orientation of the content of the curriculum of biology and chemistry at secondary schools in the Czech Republic. The qestionnaire investigating attitudes toward biology was based on work by Prokop, Tuncer and Chudá (2007).

Research methods

There exists more that one research method by which we can diagnose misconceptions (i.e. analysis of drawings and texts, interview, observation). The test is the most appropriate method for longitudinal research because we want to identify misconceptions by the greatest number of respondents. The two-tier test is introduced in a study by Treagust (1988) who presented the two-tier test as tool for investigating students' misconceptions in science education and also as a tool for possibility how to rate teachers. Treagust describes a creating of a two-tier test series of three stages with a total of ten steps. The first stage is called "Defining the Content" and includes four steps. The steps are concerned with defining the concept boundaries and involve the identification of propositional content knowledge statements and the development of a concept map (Treagust 1988, pp. 161). The second stage "Obtaining information about students' misconceptions includes three steps: "Examining relating literature", "Conducting unstructured student interview" and "Developing multiple choice content items with free response" (Treagust 1988, pp. 162–163). The third stage is "Developing a diagnostic test includes the last three steps. It "involves the development of two tier test items, of which the first tier requires a content response and the second tier requires a reason for the response" (Treagust 1988, pp. 163–164).

The research tool was administered at one secondary school in the Czech Republic. The school was an urban type. The school administrator was a teacher of biology who was instructed on how to work with the research tool. Respondents were acquainted with anonymity of test and with research purposes of study. There was no set time limit for filling out the questionnaire, but for reasonableness time was not to exceed fourty minutes.

Analysis methods

The data were re-encoded in several ways. The first analysis consolidated results from knowledge part of test: correct answer had value 1, incorrect answer value 0. To identify misconceptions, each question was evaluated separately and showen as a percentage (see Figure 5). Answers of explanation part were re-encoded so that it is possible to distinguish the correct interpretation of scientifically incorrect. Except for the percentage of misconceptions, methodology of descriptive statistics (average and determinative deviation) and inductive statistics (analysis of variance and Pearson's correlation coefficient) were also used to evaluate the data. The reliability of the research tool was determined by Cronbach's alpha which had value $\alpha = 0.43$ and indicated moderate-sized reliability of this tool.

RESULTS

The Mean score for knowledge part of the test was 0.30 (SD = 0.12) which shows a low-level knowledge about photosynthesis and plant respiration. Students responses were analysed with respect to gender, year of study and favorite subject. The results were gained on analysis of variance (ANOVA). They showed statistically significant difference between boys and girls ($F = 4.07$, $p < 0.05$) in favour to boys (Figure 1).

As regards the other observed variables (year of study and favorite subject), there were no statistically significant differences. The values of analysis of variance for variable year of study were ($F = 0.29$, $p = 0.88$), and for favorite subject were ($F = 0.05$, $p = 0.83$) (Figures 2 and 3).

Next, we examined whether there are associations between attitudes toward biology and knowledge of the tested concepts and misconceptions associated with them. The correlation between two variables was weak ($r = -0.15$) and not statistically significant (Figure 4).

For the assesment of misconceptions, we used the evaluation of each of the two-tier test items separately.

We are not only observing the number of correct answers (in knowledge part of test), but also we take

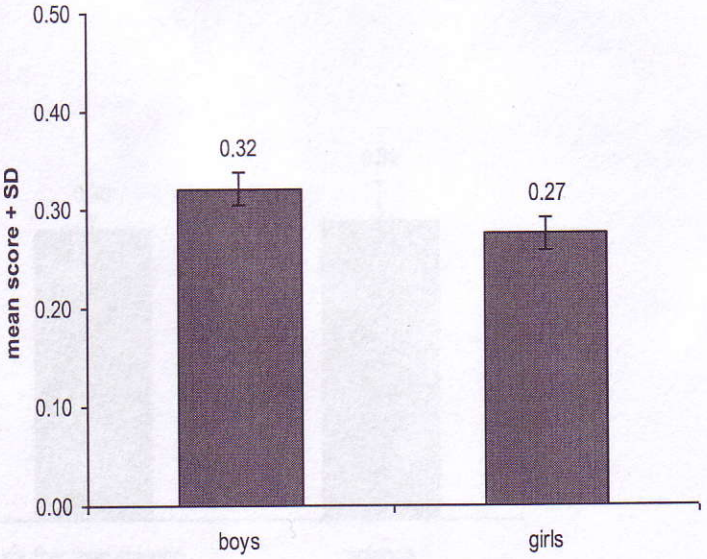

Figure 1. Analysis of the knowledge part of test according to gender

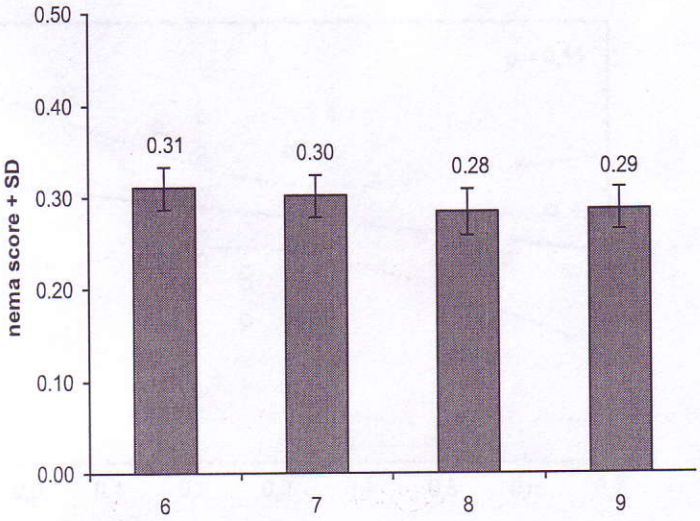

Figure 2. Analysis of the knowledge part of test according to year of study

into account the percentage of individual responses in combination with all reasons of responses (second tier of every question in test).

In item number 1 (see Figure 5), the investigated concept is whether students know if photosynthesis and plant respiration are the same processes. The results show that students do not have correct knowledge but will nevertheless choose the correct answer, however, as the students grew older, the gap between knowledge of the subject to cirriculum requirements became larger. It is in conflict with curriculum – in 9th year of study have students finish studies about plants and plant physiology and they are studying chemistry, primarily biochemistry, which is interested in chemical processes in live organisms.

Among the most frequent misconceptions is the statement that photosynthesis and plant respiration are the same processes which only differ in designation and which part of the day the processes take place (photosynthesis takes place by the day and respiration by the night). This misconception is more pronounced as the student move up in grade. Students in the 6th grade chose this response in 41.4 % of the cases, while students in the 9th grade chose this response 76.9 %. Students are not aware that breathing takes place in every cell of the plant organism, but believe it takes place in a different area than photosynthesis (in another organelle). They are also unaware that breathing takes place continuously and that it is an indispensable condition of life. This misconception may be caused by how the chemical reactions of both

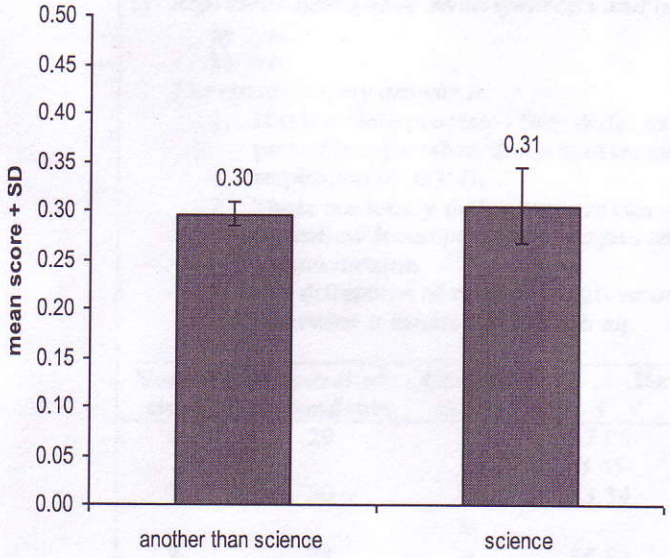

Figure 3. Analysis of the knowledge part of test according to favorite subject

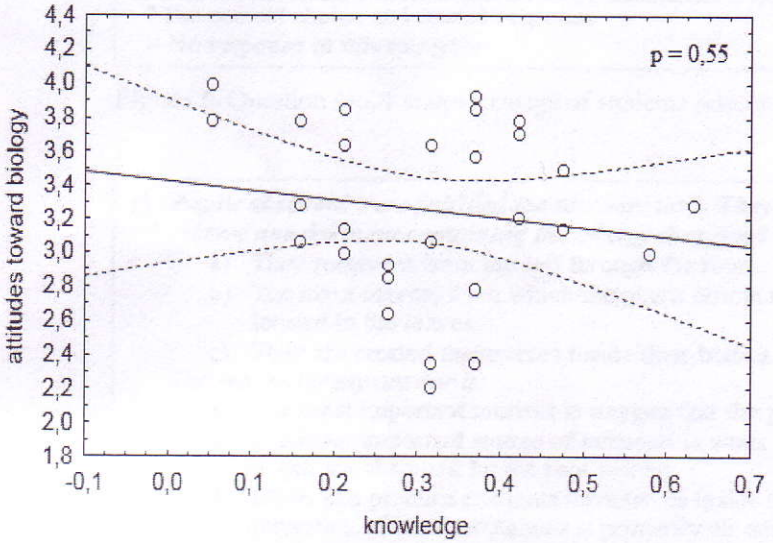

Figure 4. Interrelationship between knowledge about photosynthesis and plant respiration and attitudes toward biology

processes taught. Most textbooks and teachers treat these reactions equally –they often forget to note that this reaction take place in another place in cell and primarily under the influence of other enzymes.

Another relatively strongly represented misconception is that the plant produces oxygen during day and night. This misconception most occurred in 7th grade students (40.0 %), and least in 9th grade (23.1 %). Students often believe that oxygen release is the main purpose of photosynthesis. Also, students do not seem to understand that plants do not release oxygen by night, but instead they believe plants consume oxygen to produce carbon dioxide.

Although students often choose the correct answer that every living plant cell breaths (question four), they contradict this answer in question number eleven when they are chose the response "Respiration takes place only in leaves where the special apertures (pores) for exchange of gases are." This misconception can be attributed to the assumption that plants breathe like animals and humans. Another misconception of secondary school students is that the most important source of nutrients for the plant is water with dissolved substances which are absorbed through the root system. This response was chosen mostly by 6th grade (75.9 %) and 9th grade students (73.1 %).

1) ***Represent concepts of photosynthesis and respiration of plants the same processes?***
   a) yes
   b) no

The reason for my answer is:

1. It is the same process – they differ only in designation which is depended on the part of the day when this processes take place (photosynthesis takes place by day, respiration by night).
2. These are totally different processes – the difference is mainly in the formation/decomposition of sugars and production/consumption of oxygen and carbon dioxide.
3. The difference of concepts is given only part of the world in which they are used; otherwise it means the same thing.

Year of study	Number of respondents	Content choice	Reason response 1	2	3	No reason	Total
6.	29	A	37.93	3.44	6.90	6.90	55.17
		B	3.45	41.38*	–	–	44.83
7.	30	A	53.34	3.33	3.33	–	60.00
		B	–	30.00*	–	10.00	40.00
8.	23	A	56.52	–	8.70	–	65.22
		B	4.34	26.10*	4.34	–	34.78
9.	26	A	61.55	–	–	7.69	69.24
		B	15.38	15.38*	–	–	30.76

* The correct choice and reason response
– No response in this category

Figure 5. Question No. 1 andpercentage of students selecting alternative responses

3) ***Pupils at school were fulfilled the teachers task. They should consider where the plants receive nourishment containing the energy they need to live.***
   a) They receive it from the soil through the roots.
   b) The main source, from which the plants obtain nutrients, is chlorophyll, which is located in the leaves.
   c) They are created themselves inside their bodies.

The reason for my answer is:

1. The most important nutrient is oxygen that the plant needs to breathe.
2. The most important source of nutrients is water and the dissolved substances, which are absorbed by the root system.
3. Plants can produce nutrients themselves inside their bodies; source of energy for formation of such substances is primarily air and sunlight.

Year of study	Number of respondents	Content choice	Reason response 1	2	3	No reason	Total
6.	29	A	3.45	68.95	–	6.90	79.30
		B	3.45	3.45	6.90	–	13.80
		C	–	3.45	3.45*	–	6.90
7.	30	A	–	56.67	–	–	56.67
		B	13.33	6.67	10.00	3.33	33.33
		C	–	–	10.00*	–	10.00
8.	23	A	17.39	56.52	4.35	8.69	86.95
		B	–	8.70	–	4.35	13.05
		C	–	–	–*	–	–
9.	26	A	23.08	65.34	–	–	88.42
		B	–	7.69	–	–	7.69
		C	–	–	3.89*	–	3.89

* The correct choice and reason response
– No response in this category

Figure 6. Question No. 3 and percentage of students selecting alternative response

The correct answer "Plants created nutrients inside their bodies and the energy source for the formation of these nutrients is mainly air and sunlight" was chosen the mostly by 8th grade students. Figure 6 shows the percentage of multiple choice responses in combination with all reasons of written responses the question number 3 – "*How plants receive nourishment?*".

DISCUSSION

The main aim of this study was to identify misconceptions regarding photosynthesis and plant respiration by secondary school students. The secondary aims of the study were to determine whether misconceptions differ according to gender, year of study, favorite subject and attitudes toward biology.

The first research question was "Is there any difference between boys and girls in the level of misconceptions about photosynthesis and plant respiration?". Boys achieved higher score about knowledge regarding photosynthesis and plant respiration. These misconceptions were more frequent with girls. This contradicts the study of Haslam and Treagust (1987) who did not find differences between these two groups of respondents.

Answer to the question " How do misconceptions about photosynthesis and plant respiration change with the student's year of study?" is that the misconceptions do not change with advancing year of study. The results did not show statisticaly significant difference by students in each grade. Again, the results are different from Haslam and Treagust (1987). They present statisticaly significant difference between years of study but no interaction effects between gender and year of study.

Likewise we cannot answer the third research question "Is there any difference in the misconceptions about photosynthesis and plant respiration with the respect to favorite subject?" Both sets of students have almost the same results in the knowledge part of test and have the same misconceptions about photosynthesis and plant respiration. The results cannot be compared with the results of other authors because the study describes the influence of favorite subject on misconceptions by students and students.

On the last research question "Can attitudes toward biology be associated with the knowledge and misconceptions about photosynthesis and plant respiration?" we can answer: There are no associations between attitudes and knowledge (and misconceptions associated them). Means of Pearson's correlation coefficient was not found to significantly influence of attitude toward biology on knowledge about photosynthesis and plant respiration. The same results were found by Usak et al. (2009).

We confirm a similarity of our own findings with other authors. Students often confuse concepts of photosynthesis and plant respiration. They frequently make the mistake that plants respire carbon dioxide and not oxygen. Marmaroti and Galanopoulou (2006) presented similar assertions which were evaluated misconceptions about photosynthesis and plant respiration by thirteen year old Greek students. Authors say that students often think photosynthesis is one of the possible ways how a plant might respire. According to Özay and Öztas (2003) misconceptions are promoted through curriculum creation in Turkey. We believe, the same problem exists in the Czech Republic where these concepts are taught in several school subjects (e.g., in biology and chemistry) and in different time horizons. Another problem is that the topic of plant physiology is characterized by a large number of points of view (physiological, biochemical, energy, environmental, etc.) and each teacher prefers another method and form of teaching. We believe that inconsistent teaching style between subjects can also be one of possibilities why students do not connect the knowledge concepts. Anderson, Sheldon and Dubai (1990) in their study point out that students and students of all ages show strikingly similar misconceptions about photosynthesis. Most of misconceptions they gain on awareness about the activities of plants and plant materials without deeper knowledge of the topic.

From the point of view of acquired knowledge about plant physiology students show a relatively low level of understanding of the topic which is the primarily occurrence of misconceptions. For some answers to questions it was evident that students held preconceptions (naïve theories). We believe students would have developed these theories during the observation of the outside world and insufficient orientation on the fundamentals of plant physiology in the curriculum at primary schools. From the studies results is evident that students gain particular knowledge separately in a few subjects, in different year of study, by different teachers. As a result, students have difficulty combining concepts to have a comprehensive complex theory which can eliminate someone misconceptions. Moreover, these concepts are rather abstract, are difficult to comprehend, and obtained primarily through memory learning. The possibility of influencing misconceptions in plant physiology by extracurricular surroundings is very small because the character and difficulty of the topic. Further, most of the general public and parents of students have misconceptions about photosynthesis and plant respiration – understandably this directly predisposes students to have a preconceptions and misconceptions.

CONCLUSION

Knowledge of students' misconceptions is pivotal from the point of view of directed school education. This study was aimed to identify the most common misconceptions about photosynthesis and plant respiration by secondary school students. The research and evaluation of misconceptions are popularly held today because they enable individualization for students in education. The understanding of the existence of misconceptions will primarily they enable the development of special didactic materials (which are specific for modification and elimination of students' misconceptions). The study points to two-tier test as one of possibilities how we can diagnoze and evaluate students' misconceptions.

Our research showed that Czech students carry many misconceptions about photosynthesis and plant respiration. In particular , they mistook photosynthesis for plant respiration, they thought that plant produced oxygen throughout the day, they thought that respiration took place only in leaves and that respiration was performed in special organs,and tha the most important source of food for plants is water with dissolved mineral substances. We propose that one of ways how teachers could reduce misconceptions is a graphic representation of these concepts, correct chemical clarification of photosynthesis and respiration and connection of integration about these processes.

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REFERENCES

Anderson, C. W., Sheldon, T. H. & Dubay, J. (1990). The effects of instruction on college non-majors' conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching*, 27(8), 761–776.

Chi, M. T. H. & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In Limón, M., & L. Mason (Eds.). Reconsidering conceptual change: Issues in theory and practice (pp. 3–27). New York: Kluwer Academic Publishers.

Fisher, M. K. (1985). A misconception in biology: Amino acids and translation. *Journal of research in Science Teaching*, 22, 53–62.

Haslam, F. & Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education*, 21(3), 203–211.

Lawson, A. E. & Thompson, L. D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. *Journal of Research in Science Teaching*, 25(9), 733–746.

Marmaroti, P. & Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education*, 28(4), 383–403.

Özay, E. & Öztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education*, 37(2), 68–70.

Prokop, P., Tuncer, G., & Chudá, J. (2007). Slovakian students' attitudes toward biology. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(4), 287–295.

Sneider, C. I. & Ohadi, M. M. (1998). Unraveling students' misconceptions about the Earth's shape and gravity. *Science Education*, 82(2), 265–284.

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

Usak, M., Prokop, P., Ozden, M., Ozel, M., Bilen, K. & Erdogan, M. (2009). Turkish university students' attitudes toward biology: The effect of gender and enrolment in biology classes. *Journal of Baltic Science Education*, 8(2), 88–96.

Wandersee, J. H. (1986). Can the history of science help science educators anticipate students' misconceptions? *Journal of Research in Science Teaching*, 23(7), 581–597.

Yenilmez, A. & Tekkaya, C. (2006). Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and technology*, 15(1), 81–87.