Determination of student misconceptions in “photosynthesis and respiration” unit and correcting them with the help of cai material

Esra Keleş\textsuperscript{a} *, Pınar Kefeli\textsuperscript{b}

\textsuperscript{a} Fatih Faculty of Education, KTÜ, Trabzon, 61335, Turkey
\textsuperscript{b} Karaağaçlı Primary School, Trabzon, 61500, Turkey

Received October 26, 2009; revised December 2, 2009; accepted January 13, 2010

Abstract

Since the basic concepts in science education form the base of more advanced science topics, they should be taught correctly and meaningfully in primary and secondary school for the sake of an effective science education. This study is conducted to detect 6\textsuperscript{th} and 7\textsuperscript{th} grade students’ misconceptions on “photosynthesis” and “respiration” units and to determine the effect of the developed computer assisted instruction (CAI) material on removal of these misconceptions. The misconceptions were determined by clinical interviews conducted with the help of the prepared question cards. In order to remove the misconceptions, animations were developed to animate each picture in the question cards. The students were made to interact with these animations and misconceptions were tried to be removed by this way.

Keywords: CAI material; misconceptions; photosynthesis; respiration; education.

1. Introduction

Biology course is one of the courses that students experience difficulty with. That the course includes lots of abstract concepts may cause students have difficulty in constructing knowledge. However, one of the aims of science education is to make students learn the concepts meaningfully and to make them use the concepts to satisfy their needs in daily life (Köse et al., 2003). The studies concerning student understanding in biology course, which has a rich potential in terms of concepts, reveal that students have misconceptions on; diffusion-osmosis, photosynthesis, respiration, circulatory system, genetics and in general biology topics (Selvi & Yakışan, 2004). Since the science concepts form a baseline for the further science issues, teaching these concepts correctly and in a meaningful context is vitally important during primary and secondary school in terms of a sufficient science education (Köse et al., 2003). That is, in order knowledge to be taught persistently and correctly, existing faulty conceptions should be replaced with right ones. Previous studies proved that, if they are not corrected, the misconceptions at primary school still persist at university level in the same way (Canal, 1999).
In the last decade science field researchers have intensively focused on misconceptions, which are defined as “every piece of opinion in student answers so as to contradict or conflict to widely-accepted scientific facts.” Previous studies indicated that “photosynthesis” and “respiration” issues are topics that students have the greatest difficulty to understand and that most students have confusion (Özay & Öztas, 2003). Again, the studies came up with that; although they are taught starting from the first phase of primary school (first five years), students from all ages can have misconceptions over “photosynthesis” and “respiration” units (Tekkaya et al., 2003). Even though photosynthesis is a generative phenomenon taking place in plants, the nutrition production process of plants contradicts with the nourishment concept preoccupying students’ mind and telling that nourishment is intake process of solid and liquid substances into plant. The studies about the issue show that students are in difficulty to comprehend organic substances produced by plants by taking inorganic substances from the environment (Atik, 2007). It was also determined that most students believe that mass increase of plants is due to water and inorganic matters coming from the soil. Only a small minority of students believe that that mass increase of plants is due to water and inorganic matters coming from the soil. Only a small minority of students can associate the relation between photosynthesis and plant nutrients (Özay & Öztas, 2003). For the sake of providing a meaningful biology education, energy flow, food resources and other ecological principles should be learned well; and in order to this meaningful learning could occur, misconceptions over the related terms should be removed (Özay & Öztas, 2003).

The computer, which is getting more and more important in society, is also becoming more important and used more frequently in educational institutions. That learning environments enriched by computer applications let variety of instructional alternatives. Accordingly, the most frequently used computer assisted instructional methods can be listed as; Tutorials, Drill and Practice, Educational Games and Simulations (Ipek, 2001). With the framework of this study, the simplified form of simulations; animations are used. It is worth to investigate how effective applying animations can be on correcting student misconceptions in biology education; particularly in concept teaching.

The aim of this study is to detect 6th and 7th grade students’ misconceptions on “photosynthesis” and “respiration” issues, to develop a computer assisted instruction (CAI) material to relieve these misconceptions and to detect the efficiency of this CAI material on removing these misconceptions. Photosynthesis and respiration concepts subjected in this study are taught in “Living Things and Energy Relationships” unit in 8th grade Science and Technology course curriculum. The study was conducted with 6th and 7th graders because it was intended to detect student misconceptions before they learn the topics in the classroom setting.

2. Method

The sample of study was composed of three 6th and three 7th graders attending İhsan Koz Primary School in Trabzon Province Center in the spring term of 2008-2009 educational year. Concerning the classroom teachers’ comments, the students were chosen so as to represent one high, one middle and one low achievers from both grades. In order to detect student misconceptions, clinical interviews were conducted. In clinical interview technique, whether the student learn the concept can be investigated deeply while he/she is being interviewed about a situation or an event. In some cases, students are asked to define a concept and in addition they are expected to answer and explain why they reach that idea. The explanations by students reveal students’ understanding criteria. In these interviews the exchange starts with starter questions and by making students focus on the topic or the concept which will soon be given. Then it goes on with questions about a range of pictures (White & Gunstone, 1992). This study is also carried out with prepared “question cards”. Concerning the misconceptions remarked by the related literature, question cards was prepared along with the results of the interviews with 4 expert Science and Technology Course teacher working for different primary schools. The cards took their final form with expert opinions. The procedural stages of this study are presented in the algorithm chart in Figure 1.
In the first stage of the research, the interviews performed with prepared question cards (Figure 1). Question cards that consist of a range of 6 drawings were used in the interviews; in the meantime student answers were recorded in audial media. So as to comply with the determined misconceptions, six animations that animate the drawings in the question cards were prepared on computer. These animations include tutors with the aim of correcting the misconceptions. Necessary alterations and arrangements on these animations in CAI material were done by applying the opinions of related field education expert. A sample of the question cards used in the interviews and a sample of the page prepared to explain the drawing in the question card in CAI material are given in Figure 2. Then the animations exposed to the six students in the sample and their misconceptions were tried to be corrected. Finally, the clinical interviews reapplied with the six students with the same question cards in order to determine the effect of CAI material on removing the misconceptions.
The data obtained in this study was analyzed with qualitative data analysis method. The data recorded during the interviews were scripted by excluding pauses, vague parts and some expressions of excitement and feelings. The answers given by the participants were categorized by determining the points they agreed and the points they disagreed (Yin, 1994). The related expressions were put together under the same title (Cohen & Manion, 1989). By this way, the data of the study were analyzed regarding to the main research question and by being grouped with respect to similarities. Accordingly, the formed categories and the content of student answers that fall in respective categories were determined as: “Understanding” category explains partially or fully right scientific explanations given by students. “Misconception” category is about student explanations which are inconsistent with scientific knowledge. Finally, “Unanswered” category is the category in which students submitted “I don’t know” as explanation or gave no explanations at all (Coştu, 2002).

3. Findings

In this study designed to detect misconceptions of primary school 6th and 7th grade students about the topics in “photosynthesis” and “respiration” units, the data obtained by clinical interviews were interpreted with qualitative data analysis method. The data were classified as pre-application and post-application and presented in this section.

3.1. Data from the Pre-application Interviews

The answer keys to assess the student responses to the questions on the question cards were prepared by applying expert opinions. The responses of 6 students, who were interviewed with clinical interviews, were compared to the answer key. Then the answers were classified under the headings of; “Understanding”, “Misconception” and “No answer” and the frequency of the responses under these three categories are expressed in numbers in Table 1.

| Questions | Concepts                                  | Understanding 6th grade (f) | Understanding 7th grade (f) | Misconception 6th grade (f) | Misconception 7th grade (f) | No answer 6th grade (f) | No answer 7th grade (f) |
|-----------|-------------------------------------------|-----------------------------|----------------------------|-----------------------------|---------------------------|------------------------|------------------------|
| Question-1| Photosynthesis and light                  | 2                           | 3                         | -                           | -                         | 1                      | -                      |
|           | Photosynthesis and food                  | 2                           | 3                         | -                           | -                         | 1                      | -                      |
| Question-2| Food production                           | 2                           | 1                         | 1                           | 1                         |                        |                        |
|           | Burning food                              | -                           | -                         | -                           | -                         | 2                      | 3                      |
| Question-3| Photosynthesis & carbon dioxide           | 1                           | 1                         | 2                           | 2                         | -                      | -                      |
| Question-4| Photosynthesis & gas exchange             | 2                           | 2                         | -                           | -                         | 1                      | 1                      |
|           | Respiration & gas exchange                | 1                           | -                         | 2                           | 2                         | -                      | 1                      |
| Question-5| Carbon dioxide amount                     | 1                           | -                         | -                           | -                         | 2                      | 3                      |
| Question-6| Respiration                               | 2                           | -                         | -                           | -                         | 2                      | 1                      |

When we examine the student responses question by question; in the first question 5 of the students gave responses falling into understanding category, only one student’s answer was located in no answer category (Table 1).

When we consider the responses to the second question; two of the 6th graders submitted understanding level answers about food production, while the response of the remaining 6th grader fell into no answer category. The same two students gave responses in no answer category about burning food and the remaining was in misconception category (Table 1). The students gave explanations for this question as; “I think it happens less in the dark because it respires in the dark room. The liquid-like things in it disappear” and “…chloroplast I guess is fewer I suppose. It can’t do. It cannot use it.” These explanations show that the students thought that the decrease in the mass of the plant was caused by the loss of water or chloroplast. On the other hand, response of one of the 7th graders was in understanding level, one was in misconception and one was in no answer level for the same question.
about food production. The student who exhibited the misconception said that there will not be any changes in the mass of plants as a result of photosynthesis. The responses of the all three 7th graders were in no answer category for the question about food burning.

In the third question the main concern was carbon dioxide. Only one student in 6th grade and one in 7th gave understanding level answers to the question and the rest in both groups gave misconception level answers. Two of the students said that the absence of carbon dioxide in the medium would not cause any trouble for plants. A student noted that a plant can not survive without carbon dioxide, however explained this case by saying “It is fed with carbon dioxide.” One another student argued that plants go on respiration by consuming carbon dioxide in the daytime.

According to the findings of forth question of the interview, two of both 6th and 7th graders gave understanding level responses for the question about photosynthesis and gas exchange, and the rest gave no answer. For the question related to respiration and gas exchange; two 6th and two 7th graders gave misconception level, one 6th grader understanding level responses and the remaining 7th grader gave no answer. The majority of the students said plants cannot do respiration and some of them discoursed that plants can only respire at night. One of the students expressed his/her ideas as; “It does in daytime because in daytime, perhaps it can do it with the help of the light so for example when it is dark at night it can’t find light. That’s why…” and meant that plants undergo respiration at night since they cannot do photosynthesis. In addition some other students noted that plants take carbon dioxide from the air and release oxygen during respiration.

The aim of the 5th interview question was to collect the opinion of the students about the effect of carbon dioxide amount on photosynthesis. When the student responses examined, it was determined that only one student responded the question in understanding category and the rest of them gave no answers. The students, in general, did not know about the effect of carbon dioxide amount on photosynthesis and they could not interpret the case in any way.

While two of the 6th graders responded the sixth question with responses suitable for understanding category, the remaining one fell into misconception category by saying plants do not do photosynthesis. When it comes to responses of 7th graders; two of them were in misconception category with their responses saying plants take carbon dioxide from the air and release oxygen during respiration and the remaining 7th grader was in the no answer category.

The conducted analysis showed that 6th and 7th grade students have similar misconceptions. The student responses in the post-interviews, which were conducted after the sample were exposed to the animation, are presented in the section below.

3.2. Data from the Post-application Interviews

In order to determine the effectiveness of the material in terms of removing student misconceptions, after the students were exposed to the animations prepared to remove their misconceptions, the clinical interviews were repeated with the same questions cards used at the beginning of the process. In a similar manner, the obtained post-application data categorized under “understanding”, “misconception” and “no answer” categories. The frequencies under each of the three categories are presented in Table 2.

| Questions | Concepts                              | Understanding 6th grade (f) | Misconception 6th grade (f) | No answer 6th grade (f) | Misconception 7th grade (f) | No answer 7th grade (f) |
|-----------|---------------------------------------|----------------------------|----------------------------|-------------------------|-----------------------------|------------------------|
| Question-1| Photosynthesis and light               | 3                          | -                          | -                       | -                           | -                      |
|           | Photosynthesis and food                | 1                          | 1                          | 1                       | 2                           |                        |
| Question-2| Food production                        | 3                          | 2                          | -                       | -                           | 1                      |
|           | Burning food                           | -                          | -                          | -                       | 3                           | 3                      |
| Question-3| Photosynthesis & carbon dioxide        | 2                          | 3                          | -                       | -                           | 1                      |
|           | Photosynthesis & gas exchange          | 2                          | 3                          | -                       | 1                           | -                      |
|           | Respiration & gas exchange             | 2                          | -                          | 1                       | 3                           | -                      |
| Question-5| Carbon dioxide amount                  | 1                          | 3                          | 1                       | -                           | 1                      |
| Question-6| Respiration                            | 2                          | -                          | 1                       | 1                           | 2                      |
When the student responses to interview questions examined one by one, all of the 6th and 7th graders gave understanding level responses to the question about photosynthesis and light. About the question related to the importance of photosynthesis for plants, one of the 6th graders gave understanding level answer; one was in no answer category. However, the remaining 6th grader demonstrated a different misconception from the one in the pre-interview. The student discoursed the expression; “It is fed when it gets sunlight…” One of the 7th graders gave an understanding level response and the remaining two 7th graders gave no answers.

Examining the student responses to the second question, it can be observed that all of the 6th and two of the 7th graders submitted understanding level responses about the food production and a 7th grader was in no answer category.

When the student responses for the third question were analyzed, it is seen that two of the 6th and all of the 7th graders gave responses in understanding category for the question about the carbon dioxide. One 6th grader responded question as; “I don’t know. Next question please!” and fell into no answer category.

For the forth question, all of the 7th grade and two of the 6th grade students gave understanding level responses by denoting plants take carbon dioxide from the air and release oxygen as a result of the photosynthesis. One 6th grader did not respond the question. Related to gas exchange in respiration in the same question two of the 6th grade students were in understanding level, while the misconception of the remaining student persisted as it was in the pre-interview. The student claimed plants make respiration by using carbon dioxide when they are not doing photosynthesis. For the same question, all of the 7th grade students exhibited misconceptions. One of them meant plants do not do respiration by saying; “… then it can’t do anything in the dark…” Another student replied the question “What does it do in respiration?” as “It gets carbon dioxide and gives oxygen.” Therefore it can be said that the misconceptions of these two 7th graders persisted as before in the pre-interview. In one of the students another misconception, different from the one in the pre-interview, was detected.

As is seen in Table 2, while all the 7th graders responded the fifth questions about the amount of carbon dioxide suitable for the understanding category, one of the 6th graders gave answer in understanding, one in misconception and one in no answer categories. The answer of the one in the misconception category was; “...the plant in number 2 develops best I think because in number 1 do less respiration. Because there is less oxygen since there are two living things, it develops less...”

When the student responses to the question to detect student misconceptions about respiration were investigated, it was observed that two of the 6th graders were in understanding category and one in no answer. Two of the 7th graders were in no answer category and the remaining one responded in misconception category with the explanation; “…since the plant in the second box takes carbon dioxide and gives oxygen…” The misconception of the student persisted as it was in the pre-interview.

Comparing the pre-application and post-application findings, it can be seen that the students of 6th grade and 7th grade had similar misconceptions at the beginning (Table 3). Some newly formed misconceptions different from the previous ones were detected by the post-interviews applied after the students interacted with the CAI material. Table 3 presents the persisting misconceptions (with ‘+’ symbol) and the removed misconceptions (with ‘-’ symbol).

Table 3. Pre-application and post-application misconceptions

| Misconceptions                                      | Pre-application | Post-application |
|----------------------------------------------------|-----------------|-----------------|
|                                                    | 6th grade | 7th grade | 6th grade | 7th grade |
| The sunlight makes plants healthier, more powerful and in more beautiful color. | +     | +     | -     | +     |
| The sunlight is the food of plants.                | +     | -     | +     | -     |
| The food of a plant is water and minerals from the soil. | -     | +     | +     | -     |
| CO₂ is harmful for plants.                         | +     | -     | -     | -     |
| Plants do not use oxygen.                          | +     | +     | -     | -     |
| Plants do not use oxygen.                          | +     | +     | -     | -     |
| Respiration in plants only takes place when there is no light; at night. | +     | +     | -     | -     |

3116 Esra Keles and Pinar Kefeli / Procedia Social and Behavioral Sciences 2 (2010) 3111–3118
4. Discussion

This study was conducted with 6 students studying at 6th and 7th grades. The findings about the misconceptions, obtained with the interviews before the students interact with the animation agreed with the similar studies in the literature. The misconceptions detected about respiration like; “Photosynthesis is the respiration of plants”, “plants cannot do respiration”, “plants cannot use oxygen” or “respiration in plants only takes place at night when there is no light” are common misconceptions in similar studies (Griffard, 2001; Sacit et al., 2003; Çepni et al., 2006; Marmaroti and Galanopoulou, 2006; Yenilmez and Tekkaya, 2006). While some of the interviewee students said plants perform no respiration at all, some others argued that they do respiration only when there is no light and they cannot do photosynthesis. Some of the students did not accept respiration as an essential event for plants and moreover they were not aware of the role of food in respiration. This piece of finding was also reported by Bishop et al. (1986). As another point, only two of the students could correctly explain the reactants and products of the respiration reaction. The similarity between our findings and the findings of similar previous studies reveals that students may have similar misconceptions. The reason for students from different educational backgrounds, living in different countries and of different ages have similar misconceptions may be the similar experiences they have in their daily lives.

The misconceptions detected related to photosynthesis in this study can be listed as; “the sunlight makes plants healthier, more strong and have them more beautiful color”, “the sun is food for plants”, “CO2 is food for plants”, “the food of a plant is water and minerals taken from the earth”, “the sunlight is converted into food in photosynthesis”, “carbon dioxide is converted into oxygen in photosynthesis”, “CO2 is harmful for plants”. The determined misconceptions were also in the findings of previous studies (Canal, 1999; Sacit et al., 2003; Marmaroti and Galanopoulou, 2006; Çepni et al., 2006). As Bishop et al mentioned, students are aware of the necessity of photosynthesis to plants survive but they are not so clear about the role of photosynthesis in growing and development of plants. The students had tendency to answer the question; “how do a plant nourish?” with the answer; “substances taken from the environment”. The students who know that plants take carbon dioxide from air and release oxygen during photosynthesis interpreted the photosynthesis as a simple gas exchanging phenomenon. Finally, one of the students thought that carbon dioxide is harmful for plants and he/she said that increase in carbon dioxide amount would adversely affect plants. This single misconception was different from the misconceptions reported by previous studies.

When the number of misconceptions that the students bear after they were let interact with CAI material compared with the number of misconception before the application, a sharp decrease was detected. Some of the still persisting misconceptions were on respiration and some others were about plant nourishment. Such conceptions which are hard to change are called robust concepts (Çepni and Keleş, 2006). Besides these ongoing robust misconceptions, some other newly formed misconceptions were also detected during the second set of interviews. Since the same group of students were also interviewed prior to the application, the students were observed more relaxed in the post-application interviews. This situation may have been the reason of students give more detailed answers and the different misconceptions came out.

As a result of this study, it was determined that CAI materials are effective in removing pre-determined misconceptions. This result of the present study complies with the results of some previous studies (Köse et al., 2003; Büyükkasap et al., 1996). This result which was obtained at the end of the study may have been caused by concretizing potential of the animations in abstract issues, their attractivity provided by visuals and their capacity of facilitating persistent learning by appealing more than one sense organ. Thus it can be said that such animations may remove misconceptions and facilitate further knowledge is constructed correctly.

5. Conclusion and Recommendation

A fall was detected when the number of misconceptions that the students have before the application compared with the number of misconception after they were made to interact with CAI material. It was revealed that the misconceptions which could not be removed were mainly about “respiration” topic and secondly on “plant nourishment.” The students had difficulties in understanding that plants perform “respiration” and “photosynthesis” at the same time. The study came up with the result that the students perceive nourishment for plant as “intaking substances from outside” just like it is for human and animals. Backed with the available results, following recommendations are noted for further studies:
Teachers should first remove misconceptions of students so that students can learn new concepts in a meaningful context. To do so, misconceptions should be detected in the first place. Teachers should be able to use different methods and materials for this aim. Therefore, teachers should be informed about concept teaching and misconceptions.

Animations should be used in the instruction of abstract and hard-to-learn topics like photosynthesis and respiration. It would be fruitful that field experts and educational technologists collaborate on preparation of such animations.

Teachers should be informed about utilizing technology in education by in-service trainings launched to train teachers about how to integrate CAI materials into their instruction and how to use them effectively.

Similar studies with a larger sample and in a longer time may be conducted. Studying with longer periods may help to determine the effectiveness of animations and whether misconceptions resist to the change.

Similar studies with the aim of determining the effectiveness of CAI materials on removing misconceptions should be applied in different topics of Science& Technology course curriculum. By this way, materials suitable for different topics in Science& Technology course could be developed and their efficiency on removing misconceptions could be discussed.

References

Atık, Y. (2007). Fotosentez konusu için rehber materyal geliştirilmesi. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Bakt, A., Karaş, İ., & Güven, B. (2007). Klinik mülakat yöntemi ile problem çözme becerilerinin değerlendirilmesi. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Bishop, B. A., Roth, K. J. & Anderson C. W. (1986). Respiration and photosynthesis: a teaching module. Michigan State University, Michigan.

Brown, M. H. (2005). Understanding photosynthesis and plant cellular respiration as "nested systems": the characterization of pre-service teachers' conceptions. Western Michigan University, The Mallinson Institute of Science Education, Michigan.

Canal, P. (1999). Photosynthesis and 'inverse respiration' in plants: an inevitable misconception. International Journal of Science Education, 4, 363-371.

Carlsson, B. (2002). Ecological understanding 1: ways of experiencing photosynthesis. International Journal of Science Education, 7, 681-699.

Çepni, S. (2006). The effects of computer-assisted material on students cognitive levels, misconceptions and attitudes towards science. Computers & Education, 46, 192-205.

Çepni, S., & Keleş, E. (2006). Turkish students' conceptions about the simple electric circuits. International Journal of Science and Mathematics Education, 4, 269-291.

Coştu, B. (2002). Örtaöğretimin farklı seviyelerindeki öğrencilerin buharlaşma yönləşməsə ve qaynamə kavramlarını anlama düzeylerine ilişkin bir çalışma. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Trabzon.

Dilek, F. N. (2006). Sekizinci sınıf öğrencilerinin fotosentez ve solunum konularını kavramalarını ve fene karşı tutumlarını çoku zeka modelinin etkisi. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Griffard, P. B. (2001). The two-tier instrument on photosynthesis: what does it diagnose? International Journal of Science Education, 10, 1039-1052.

Köse, S., Ayas, A., & Taş, E. (2003). Bilgisayar destekli öğretimin kavram yanılgıları üzerine etkisi: fotosentez. Pamukkale Üniversitesi Eğitim Fakültesi Dergisi, 14, 106-112.

Köse, S., Coştu, B., & Keser, F. (2003). Fen konularındaki kavram yanılgılarının belirlenmesi: tqa yöntemi ve örnek etkinlikler. Pamukkale Üniversitesi Eğitim Fakültesi Dergisi, 13, 43-53.

Lin C. Y., & Hu, R. (2003). Students’ understanding of energy flow and matter cycling in the context of the food chain, photosynthesis, and respiration. International Journal of Science Education, 12, 1529-1544.

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

Orhan, A. T., Kesici, D., Memiş, H., & Okur G. (2004). Fen bilgisi öğretmen adaylarına fotosentez konusunun öğrettilmesinde yapışal yaklaşımın etkileri ile geleneksel öğretim yönteminin etkilerinin karşılaştırılması. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

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

Selvi, M., & Yakışan, M. (2004). Misconceptions about Enzymes in University Students. Gazi Eğitim Fakültesi Dergisi, 2, 173-182.

Tekkaya, C., Çapa, Y., and Yılmaz, Ö. (2000). Pre-service Biology Teachers’ Misconceptions about Biology. Journal of Hacettepe University Education Faculty, 18, 140 – 147.

Tekkaya, C., and Balci, S. (2003). Determined Students’ Misconceptions Photosynthesis and Respiration. Journal of Hacettepe University Education Faculty, 24, 101–107.

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, 81-87.